VOL. L, NUMBER 2 WHOLE NUMBER 419

THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

EDITOR, C. A. CHANT ASSISTANT EDITOR, RUTH J. NORTHCOTT

David Dunlap Observatory
Richmond Hill P.O., Ont.

ASSOCIATE EDITORS:

C. S. BEALS
Dominion Astronomer
Ottawa

R. M. PETRIE
Dominion Astrophysicist
Victoria, B.C.

A. THOMSON
Controller of the Meteorological Service of Canada, Toronto

PUBLISHED BI-MONTHLY

March-April, 1956

PRINTED BY

THE UNIVERSITY OF TORONTO PRESS

The Royal Astronomical Society of Canada

OFFICERS FOR 1956

NATIONAL OFFICERS AND COUNCIL

Honorary President—The Honourable W. J. DUNLOP, Minister of Education for Ontario.
President—R. M. PETRIE, PH.D, Victoria.
First Vice-President—HELEN S. HOGG, PH.D., Toronto.
Second Vice-President—GORDON R. MAGEE, PH.D., London.
National Secretary—E. J. A. KENNEDY, 13 Ross Street, Toronto.
National Treasurer—J. H. HORNING, M.A., 13 Ross Street, Toronto.
Recorder—FREDERIC L. TROYER, Toronto.
Librarian—J. B. OKE, PH.D., Toronto.
Council—D. C. BAWTENHEIMER, Windsor; Rev. M. W. BURKE-GAFFNEY, Halifax; J. A. BUTEAU, Montreal; BRIAN COCKHILL, Montreal; H. B. FOX, Hamilton; MRS. K. M. HEATON, Toronto; R. J. LOCKHART, Winnipeg; D. A. MACLULICH, Ottawa; ANDREW MCKELLAR, PH.D., Victoria; E. E. O'CONNOR, London; E. PHIBBS, Edmonton; G. M. SHRUM, PH.D., Vancouver; OSCAR VILLENEUVE, Quebec.

TORONTO CENTRE

Honorary President—C. A. CHANT, PH.D.
First Vice-President—GRANT A. COOPER
President—H. L. WELSH, PH.D.
Second Vice-President—C. FRANK PUBLOW, B.A.SC.
Secretary—FREDERIC L. TROYER, 53 Woodlawn Avenue East, Toronto 7.
Recorder—RAYMOND R. BROADFOOT
Treasurer—M. A. ALTMAN, C.P.A.
Council—ADAM BELL; KURT FRENKEL; DAVID J. GERRIE, B.A.SC.; D. A. MACRAE, PH.D.; MRS. ETHEL M. MORGAN, M.D.; W. R. SHERRICK; F. W. TOMINGAS, M.D.; W. T. TUTTE, PH.D.; J. B. WALLACE, and the *Past Presidents*—E. J. A. KENNEDY; J. R. COLLINS; S. C. BROWN; REV. D. W. BEST, D.D.; MISS RUTH J. NORTHCOTT, M.A.; JOHN F. HEARD, PH.D.; F. L. TROYER; W. R. HOSSACK and L. H. CLARK.
Director of Telescope Makers Group—JESSE KETCHUM, 7 Thirteenth Street, Toronto 14.

OTTAWA CENTRE

Honorary President—HOYES LLOYD
First Vice-President—J. E. LILLY
President—A. E. COVINGTON
Second Vice-President—IAN HALLIDAY
Secretary—D. L. G. MILLER, Dominion Observatory, Ottawa.
Recorder—MISS J. D. B. STEWART
Treasurer—S. A. MOTT
Representative Observers' Group—GORDON GRANT
Council—MRS. IAN HENDERSON; F. W. MATLEY; W. L. ORR; J. A. ROTTENBERG; R. W. TANNER; and *Past Presidents*—P. M. MILLMAN; D. A. MACLULICH; J. L. LOCKE.

HAMILTON CENTRE

Honorary President—W. T. GODDARD, B.S., E.E.
First Vice-President—REV. N. GREEN, B.A., L.TH.
President—J. H. SLED, PHM.B.
Second Vice-President—W. J. SLED, B.A.
Secretary-Treasurer—GEORGE MURCHIE, 77 Fennel Avenue West, Hamilton.
Curator—G. E. CAMPBELL, M.A.
Council—J. G. CRAIG, B.SC.; P. EWANICK; W. K. HARRIS; A. E. JOHNS, PH.D.; L. O. JONES; E. LANGLEY; R. LEEDS; W. S. MALLORY, M.A.; W. J. MCCALLION, M.A.; T. M. NORTON; O. J. PATON; C. PIERSON; F. SCHNEIDER; W. D. STEWART, B.A.; B. WISHART.

WINNIPEG CENTRE

Honorary President—H. H. SAUNDERSON, PH.D.
Vice-President—G. MARCY WISEMAN
President—R. J. LOCKHART
Secretary-Treasurer—T. CAIRNS, 924 Waterford Ave., Winnipeg 9.
Recorder—MISS N. TWEEDIE
Council—J. L. GREEN; C. R. PUNSHON; G. L. SADLER; J. SCATLIFF; W. W. WRIGHT; and *Past Presidents*—D. R. P. COATS; V. G. MARTENS; *President Emeritus*—L. T. S. NORRIS-ELYE.

VICTORIA CENTRE

Honorary President—K. O. WRIGHT, PH.D.
First Vice-President—E. R. GIBSON
President—MISS JEAN K. MCDONALD, PH.D.
Second Vice-President—N. G. ROGERS
Secretary-Treasurer—D. H. ANDREWS, Dominion Astrophysical Observatory, Royal Oak.
Recorder—J. L. D. JERVIS
Director of Telescopes—ROBERT PETERS
Librarian—O. W. SMITH
Council—E. R. BROWN; N. HUTCHINGS; C. D. MAUNSELL; J. A. L. MUIR; W. STILWELL; F. R. WILLIAMS.

THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY
OF CANADA

VOL. L, NO. 2 MARCH–APRIL, 1956 WHOLE NO. 419

FINDING THE DISTANCES TO THE STARS*

BY R. M. PETRIE

THE measurement of the distances to the stars is perhaps the most formidable practical problem challenging the astronomer. In testimony to this difficult task is the fact that the efforts of several generations of astronomers did not meet with success until just a little more than a century ago (1838). It is evident that the direct measurement will always present difficulties when one recalls that the available base-line—the diameter of the earth's orbit—is only some 186,000,000 miles, while even the nearest stars are distant several hundred thousand times that amount. The annual displacements of the stars are ordinarily a few hundredths or even thousandths of a second of arc and, except for our nearest neighbours, the errors of measurement soon equal or exceed the angle to be measured.

The situation is particularly severe for those very luminous and high-temperature objects called the B stars. They are relatively rare among the stellar population and all but one or two are beyond the reach of direct measurement. Yet these are the stars whose distances we must know if we are to study the dynamics of the stellar population and understand the forces prevailing in our galaxy. The B stars are so bright, intrinsically, that they and only they can be observed in sufficient numbers and at adequate distances for effective galactic studies. We must know how far away they are.

The fundamental difficulty, outlined above, led astronomers in the early decades of the century to a search for spectroscopic clues as to the intrinsic brightness of a star. Knowledge of the true brightness of a star

*Presidential Address delivered at the At-Home of the Royal Astronomical Society of Canada, February 17, 1956. This material was also the substance of the Presidential Address to Section III, Royal Society of Canada, June 1956.

will at once give us the distance when comparison is made with the apparent brightness. Thus if l is the apparent brightness, easily measured, and L is the intrinsic brightness referred to some standard distance R, then the star's distance r is at once found from:

$$r = R\left(\frac{L}{l}\right)^{1/2} \tag{1}$$

The astronomer usually writes this as:

$$\log r = 1 + 1/5\ (m - M) \tag{2}$$

where m is the apparent magnitude and M is the absolute magnitude. Magnitude is the term for brightness expressed on a logarithmic scale. The absolute magnitude gives the brightness of the star as it would appear if seen from the standard distance of ten parsecs (33 light-years). It will be obvious that if we have some means of assigning M, say from spectroscopic evidence, we may at once compute the distance r from equation (2). This is the method of "spectroscopic parallaxes" which has had some remarkable successes. It is proposed to describe in this lecture the application of the method to the B-type stars as developed recently at the Dominion Astrophysical Observatory.

It should be noted that, if we are to derive spectroscopic parallaxes for B-type stars, our methods must supply M with considerable precision. From (2) we have:

$$\delta\ r = 0.45 \times r \times \delta\ M \tag{3}$$

A fairly gross error, $\delta\ M$, may be tolerated if we are dealing with nearby stars, but high accuracy is demanded if we are to study galactic structure. Thus, at a distance of 3000 parsecs (10,000 light-years), an error of 0.25 in M results in a distance uncertainty of nearly 350 parsecs. An error of this size makes it impossible to study the details of galactic structure, and difficult even to delineate the major features. Obviously we must exercise the greatest care in finding M.

The search for spectroscopic indicators of luminosity, in B-type spectra, began about 1920 and first results were obtained in England in 1922 and the United States in 1923. The first studies dealt with the intensity ratios of certain pairs of lines. A significant change of method was indicated in 1929 when it was realized that the strength of the absorption lines of hydrogen (Balmer Series) was closely related to stellar luminosity, at least in the spectra of the hot stars. The dependence can be demonstrated quite well when one plots the brightnesses of stars belonging to a cluster (all at a common distance, presumably) against the strength of hydrogen

absorption in their spectra. The effect is shown in figure 1 for members of the Pleiades cluster.

The explanation of, and justification for, the use of hydrogen in absorption is found in the original discovery and treatment of Stark effect, and in fundamental experimental work such as that of Foster. It can be shown that, for a given temperature, the very luminous stars possess

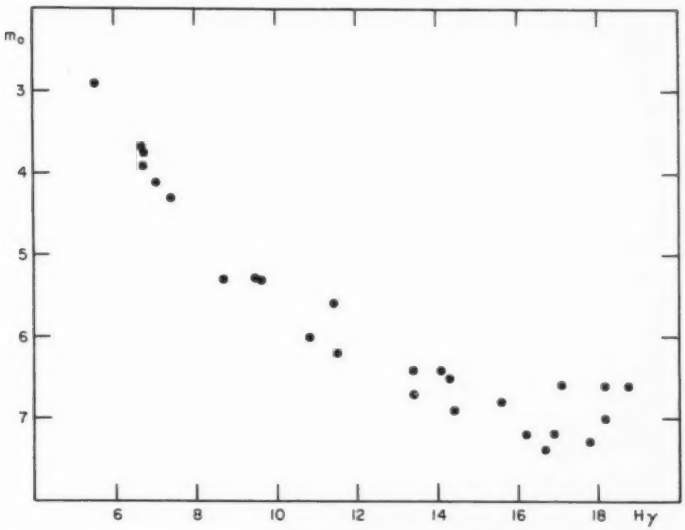

FIG. 1—The apparent magnitudes plotted against hydrogen absorption for members of the Pleiades. Since all the members are at the same distance from us, this demonstrates the correlation between absolute magnitude and hydrogen line absorption.

tenuous atmospheres while the fainter stars exhibit atmospheres of relatively high density. The atoms in the dense atmospheres of these latter, so-called dwarf stars are subject to a strong fluctuating electric field which blurs the sharpness of the Stark components and merges all into a wide strong line. In the rarefied atmospheres of supergiant stars the atoms are little disturbed by neighbouring ions and the absorption lines of hydrogen remain narrow and relatively weak. The luminosity effect at Hγ is shown in figure 2 where one sees the remarkable variation between the supergiant and dwarf.

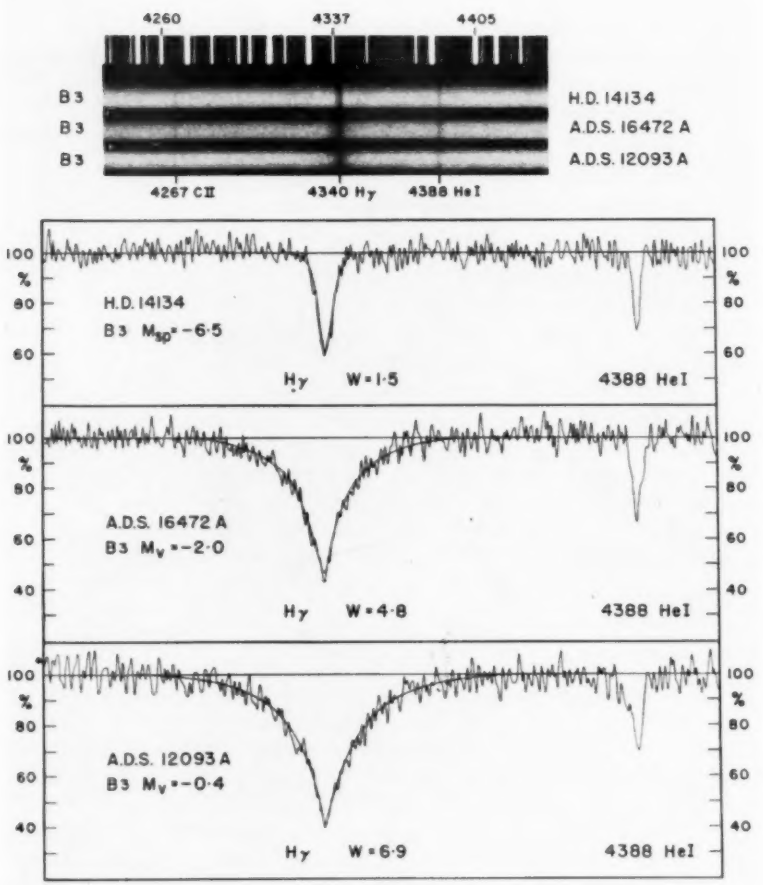

FIG. 2—The region of Hγ in the spectra of three B3 stars. The intensity records show the remarkable increase in hydrogen absorption between the very luminous star H.D. 14134 and the relatively faint star A.D.S. 12093A. The variation is not fully appreciated in a visual inspection of the spectrograms.

The sensitivity of hydrogen to stellar luminosity is a particularly happy circumstance for the astronomer. The advantages are:

(a) The hydrogen lines are present over a wide temperature range, and show little variation with temperature in B spectra.

(b) The lines are strong features, hence they may be measured with sufficient precision.
(c) Stellar atmospheres are composed largely of hydrogen so that the criterion should be little affected by changes in chemical abundance.

It is now generally recognized that the hydrogen lines are the best indicators of luminosity for the high-temperature stars.

The Calibration

Two things are necessary before we can apply the foregoing information to find absolute magnitudes and distances. They are:
(a) means must be devised to measure the strength of the hydrogen absorption, and
(b) the form of the absolute-magnitude dependence must be found from observational material, since this cannot yet be predicted from theory.
The first requirement is readily met by methods of spectrophotometry now developed and densitometers now available. The second posed the real difficulty since for its solution we require the absolute magnitudes of a sufficient number of B stars, and this is precisely the information which is lacking. It was possible, however, to obtain the necessary standard stars, as follows:
(a) By studying galactic clusters containing both B-type members and "later"-type members. The distances of the clusters were then found from the non-B-type members by spectroscopic methods already found to be satisfactory.
(b) By utilizing in a similar way visual binary systems composed of B-type, and non-B-type, components.
(c) By using eclipsing binary systems in which the radii of the component stars are known. The radii and the surface temperatures (deduced from the spectra) allow one to compute the absolute magnitudes.

The necessary telescopic work having been done, it was possible to find ninety-nine standard B stars. The adopted absolute magnitudes and the measured absorptions of $H\gamma$ then furnished the material for the calibration, which is shown in figure 3. This represents our solution of the problem and may now be used to obtain absolute magnitudes and distances for any B star for which the absorption at $H\gamma$ can be measured.

It is evident from figure 3 that there is a considerable scatter in the individual points about the mean correlation. Fortunately it may be demonstrated that the scatter may be accounted for by the uncertainties in assigning standard magnitudes and in the measures of absorption. This is an important conclusion since it means that the "intrinsic" scatter is small and for the great majority of B stars we may probably use the $H\gamma$

criterion. It may be remarked that the present measures of Hγ rest upon two spectrograms per star and the measurement error, for an average star, corresponds to a probable error of $\pm$ 0.2 in *M*. This is adequate for present purposes and, when needed, the accuracy may be improved by increasing the number of measures per star.

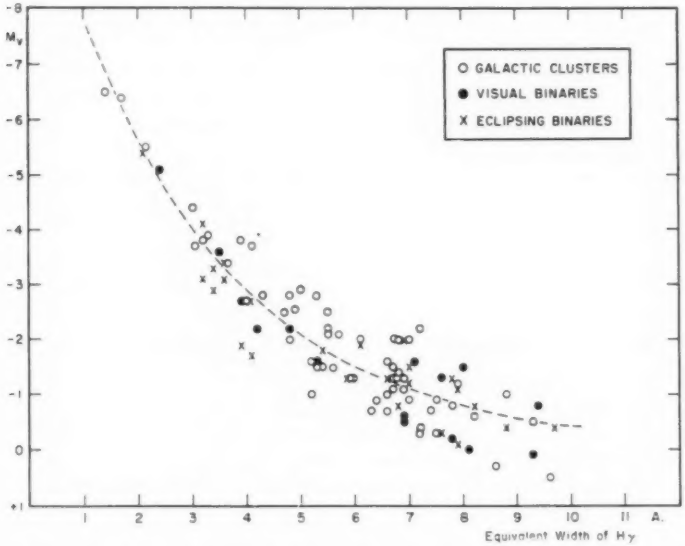

FIG. 3—The correlation between hydrogen line absorption and absolute magnitude for 99 standard stars.

Tests of the Calibration

The accumulation of measures of Hγ has now grown to a total of about 400. With this material it is possible to test the accuracy of the calibration in a way independent of the original determination. Two statistical tests may be made, as follows:

(a) *Mean Parallaxes from Proper Motions.* The apparent angular motions of stars (proper motion) depend, on the average, upon the amount and direction of the sun's motion and the distances of the stars from the sun. Assuming that the peculiar motions are at random, we may then find the mean distance of a group of stars since the solar motion is well known. The method is reliable for nearby stars but decreases rapidly in accuracy for

the more distant groups because of the minuteness of the proper motions. We can test our spectroscopic parallaxes by comparing the average value for a sufficient number of stars with the average calculated from the proper motions.

The test is most reliable when applied to the "dwarf" stars which are relatively near to us. The average spectroscopic parallax for 177 of these stars is 0".0053 and the average computed from the proper motion is 0".0051. That part of our calibration which contains the dwarf B stars (absolute magnitude fainter than — 2.0) is thus confirmed. The more distant "intermediate" and "giant" stars cannot be tested properly by this method because the proper motions are generally small and cannot be relied upon to give accurate results.

(b) *Mean Distances from Galactic Rotation.* The rotation of our galaxy causes the radial velocities of stars to vary in a sinusoidal manner, doubly periodic in galactic longitude. The amplitude of this variation depends directly upon distance from the sun, and we may hence derive the mean distance of a group of stars from their measured radial velocities. The method is inaccurate for nearby objects but becomes increasingly reliable as the distance increases. It supplements very well, therefore, the method of mean parallaxes from proper motions. For 111 stars of intermediate brightness (absolute magnitudes between — 2.0 and — 4.0), the average distance by the spectroscopic method is 620 parsecs while galactic rotation gives a mean distance of 560 parsecs. The galactic rotation test is most powerful for the very distant giants (absolute magnitudes brighter than — 4.0). We have stellar velocities for 61 stars which have been measured for spectroscopic parallax. The average distance according to our calibration is 1275 parsecs while galactic rotation gives 1170 parsecs.

It should be noted that we may also employ the velocities of the interstellar material as an independent test, since the matter between the stars shares in the general galactic rotation. Interstellar velocities associated with 77 of the stars in the intermediate group referred to above give an average galactic rotation distance of 510 parsecs, and for this group of stars the spectroscopic distance is 525 parsecs. For 54 stars of the distant group we have the associated velocities of the interstellar matter, from which the galactic rotation distance is 1150 parsecs. For the same stars, the average distance determined from the Hγ intensity is 1175 parsecs.

The various statistical tests tell us that the spectroscopic estimation of absolute magnitude, based upon the strength of hydrogen absorption, has been successful and may be used in assigning distances to B-type stars for

exploration of the galaxy. It may be mentioned that a different kind of test, comparing the measured and calculated luminosities of eclipsing binary stars, also supports the spectroscopic calibration.

Having developed and tested the spectroscopic method we may look forward to more precise studies of the B stars, those near the sun, as well as those at greater distances in the galaxy. Distances have been measured now for some 400 stars and this sample will be increased several times in the near future as our current programme progresses. It should soon be possible to give an adequate description of the distribution and motions of the early-type stars and the interstellar gas in the galaxy within 5000 light-years of the sun.

The B stars are very luminous compared with the average stellar population and among themselves they vary tremendously in luminosity. An "average" B star is found to have about three hundred times the radiance of our sun, but the more brilliant representatives are much more luminous than that. We know of a number of these hot stars whose radiations are fully 25,000 times that of the sun. As our determinations of absolute magnitude accumulate we shall then learn also of the distribution of true brightness among the B stars.

Dominion Astrophysical Observatory,
Victoria, B.C.,
January 1956.

THE FORMATION OF THE PLANETS,* PART I

By Gerard P. Kuiper

Formulation of the Problem

The problem of the origin of the earth and its sister planets has been of great philosophic interest throughout the ages. It is not a foregone conclusion, however, that the problem has a scientific solution. For instance, an enclosure in which the air has been stirred gives, after some delay, no clue on the nature or the time of the stirring. All memory of the event within the system has been lost.

The solar system is not infinitely old, however, and shows many properties that must depend directly or indirectly on its mode of formation. Its age is, in round figures, 5000 million years, based on analyses of terrestrial and meteoritic materials containing natural radioactive isotopes and their decay products—though some uncertainties remain in their interpretation. The age of the sun cannot at present be accurately determined. Ledoux (1949) computed the value 5×10^9 years; but the adopted model was found subsequently to require revision; an appreciable outer convection zone appears to be present while there is still uncertainty about the presence of a convective core (Strömgren, 1953). For these and other reasons it is at present unsafe to estimate the age of the sun directly (Strömgren, 1955). However, it is impossible to conceive that the sun should be younger than the planets, i.e. less than 5×10^9 years. Since further, the age of the globular clusters, which is almost certainly greater than the age of the sun, has from the rate of the evolutionary processes been estimated to be about 5×10^9 years (Sandage, 1953) or 6×10^9 years (Hoyle and Schwarzschild, 1955), it nevertheless follows that the age of the sun is close to 5×10^9 years, and hence essentially the same as that of the planets. This compels one to inquire whether the formation of the planets and of the sun cannot have resulted as parts of the same basic process, which must be that of stellar formation in general.

Stellar formation is the process whereby stars form from pre-existing nebular clouds. This process is not merely hypothetical; it appears to occur before our eyes in several nebular regions. The initial dimensions of these clouds must have been nearly as large as the distances between stars. Therefore, an enormous contraction, by about 10^7 times, had to pre-

*Lecture delivered at a joint meeting of the Royal Canadian Institute and the Royal Astronomical Society of Canada, November 12, 1955.

cede the formation of a stable star. Velocity measures within galactic nebulae as well as dynamical considerations indicate that the pre-stellar clouds will, in general, have had some internal motions. On probability grounds, these internal motions will, in general, not have resulted in zero total angular momentum for a given cloud. Because angular momentum is conserved, contraction will often have been arrested long before the mass attained stellar dimensions. Instead of a single star, a double or multiple star may thus have resulted (cf. Kuiper, 1955). Binary and multiple stars are indeed very common; more than half the stars of the galaxy appear to be members of double or multiple systems. It is therefore suspected that the formation of the planetary system was related to this common process of binary-star formation. Parenthetically, it was this thought that led the writer in the early 1930's, after some frustrated attempts at understanding the origin of the planetary system, to the study of binary-star statistics.

With the age of the planets defined and the general mode of origin suggested, one must next examine whether the planetary system, just after its formation, was physically and dynamically essentially the same as today; or whether important subsequent evolution took place. In other words, there must have been a *formative* period during which the sun and the solar system segregated, and planet-like bodies first developed, followed by what may be called the *geologic* period, which began at the epoch T_g, some 4–5 billion years ago. Before we can clearly see what a theory of origin must contain, we must get a picture of the evolutionary changes which the planets and their orbits underwent during geologic time.

Planetary Evolution During Geologic Time

There are several evolutionary effects whose importance we shall examine one by one.

Solar radiation effects. The physical condition on a planetary surface depends in part upon its equilibrium temperature, i.e. on the planet's mean distance from the sun, a, and the solar luminosity, L. If the sun had ever gone through a nova stage—as has sometimes been supposed—drastic changes on the planets would indeed have occurred. Solar evolution is now known well enough to rule out this possibility. After passing through a comparatively rapid contraction phase (Helmholtz-Kelvin time scale) the sun has changed very little. In my earlier papers I used the round figure 10^8 years for the duration of this contraction phase. It has now been computed more carefully by Strömgren (1955) who has found 8×10^7 years. The last 3×10^7 years of this interval have been studied

independently and in considerable detail by Henyey *et al.* (1955), who published computed evolutionary tracks. The maximum brightness, occurring toward the close of the contraction phase, was found to be almost identical to the present solar luminosity; while the brightness at the very end of the contraction phase was about 20 per cent. lower than at present, this difference having been traversed slowly and gradually during the entire geologic era (Henyey, 1955). This very slow increase is still continuing.

At present, with an average albedo of 0.36 (Danjon, 1954; Byers, 1954), the earth has a mean *radiation* temperature* of 250°K. (— 23°C.). Below we find that at T_g the earth had probably essentially the same mean distance from the sun as today. If, further, the albedo were also the same, the mean radiation temperature would have been 5 per cent. or 12°C. lower, or 238°K. The present mean *surface* temperature is some 30°C. higher than the radiation temperature because of the "greenhouse" effect of the atmosphere; the chief constituents responsible for this effect are water clouds, water vapour, ozone, and carbon dioxide. Some of these factors may have been different at T_g: ozone may have been nearly absent and water vapour scarce because of the lower temperature. These effects plus the lower radiation temperature might have caused a lower surface temperature; the polar caps may therefore have been larger than they are now, and the albedo higher than 0.36, which would cause a further reduction in surface temperature. If, on the other hand, water was initially very scarce, as on Mars today, then a somewhat lower albedo and a higher mean surface temperature, approaching 0°C., may have existed. At any rate, the surface temperature on the earth in the early Pre-Cambrian was probably somewhat less than it is today. The picture is, however, made more complex by the occurrence of glacial periods even quite recently, indicating a climatological instability in the difference between the radiation temperature and the mean surface temperature (cf. Brooks, 1951).

More significant than the planetary surface temperatures are, for our purpose, the temperatures of the planetary exospheres; they determine the planetary mass losses. Because of the indicated solar history, the evaporation rates at T_g will have been somewhat less than at present. Since, astronomically speaking, the rates are negligible now, present planetary *masses* (and compositions) will apply at T_g.

Internal effects. While the planetary masses and global compositions have not changed since T_g (with the understanding that T_g may not be quite

*The radiation temperature is a measure of the total amount of radiation lost to space; it balances the absorbed solar radiation.

the same for each planet), internal rearrangements must have taken place. The best known of these are the changes in the earth's crust and atmo-hydrosphere, although opinions differ on the extent to which these changes are cyclic or progressive. In other words, have the continents grown from nuclei during geologic time or have they always been roughly of present size and have been merely reworked? The arguments for these respective views are well presented in two recent books (Wilson, 1954; Poldervaart, 1955). There is also uncertainty on the origin of the terrestrial hydrosphere. While the evidence of the whole appears to favour its development from the earth's interior during geologic time, as is true for the atmosphere (Rubey, 1955, and references given there), there is also the result that the water vapour now exhaled by volcanoes is not original (juvenile) but all or nearly all recirculated (Craig and Boato, 1955).

Evidence for other internal rearrangements comes from lunar studies (Kuiper, 1954, and references given there) and from well-known studies of meteorites, fragments of the asteroid ring. These bodies show that widespread melting has occurred which is attributed at least in part to heating by their radioactive constituents (U^{235}, U^{238}, Th, K^{40}, etc.). For the larger planets considerable heating derived also from the potential energy released upon the formation of a high-density core (Urey, 1952). Internal thermal evolution must have affected all planets and all but the smallest satellites (where thermal conductivity prevented accumulation of heat); and one might, of course, regard the development of continents and an atmo-hydrosphere as accompanying features of such a thermal evolution. The atmospheres of Venus and Mars may thus be regarded as evidence for such evolution. The same is probably true for the presence of a planetary magnetic field. Since all planetary interiors presumably are, or at least have been, above the Curie point of iron (about 750°C.), a planetary magnetic field is supposed to require the presence of a liquid core. Thus the moon will probably have no such field while Venus and the Jovian planets probably do. (A field for Venus has been suspected empirically by Houtgast, 1955, but this is not established.) The structure of the Jovian planets must likewise have changed during geologic time. The major outbursts observed on both Jupiter and Saturn every decade or so—unaffected by solar radiation, occurring as they do at random positions along the eccentric orbits—show that the interiors still furnish significant quantities of heat to the atmosphere. This is consistent with the large initial heat content expected for massive planets (e.g. Kuiper, 1952, p. 326). Consequently, early in geologic time these planets must have differed visibly from the present. For instance, the surface temperature of

Jupiter may well have been around 500°K., and at least its present type of cloud cover will have been absent. Yet, even these changes do not appear to affect our main problem, that of planetary formation. While the radius of Jupiter will have been slightly larger owing to the higher internal temperature, and hence the velocity of escape slightly less, the solar luminosity was some 20 per cent. less and escape by evaporation would have been no greater than today; that means, it was entirely negligible.

One problem of rearrangement is, however, directly related to our main theme. Both Jupiter and Saturn now possess a greater angular velocity at the equator than elsewhere. In the case of Jupiter only the bright equatorial zone itself stands out, having a period of rotation 5 min., or nearly 1 per cent., less than the remainder of the planet (minor differences exist between the other zones). In Saturn the period of rotation appears to be a smooth function of latitude, being 11 per cent. greater at 57° than at the equator (Moore, 1939). No convincing explanation of this "equatorial acceleration" has been given on the basis of a global circulation system. Recently the writer found that the explanation may be similar to that proposed by Cowling (1953) for the equatorial acceleration of the sun, namely that a *fossil gaseous ring* is involved, a remnant of the disk surrounding the body at the time of planetary formation. The time scale of equalization of angular velocity of adjacent gaseous rings by viscosity is $\rho l^2/\mu$, in which ρ is the density, l the dimension and μ the coefficient of viscosity. Now ρ is probably between 10^{-3} and 10^{-1}, l may be limited by the depth of the atmosphere rather than the width of the zone, and be therefore more nearly 10^8 cm. than 10^9 cm., while the coefficient of molecular viscosity is about 10^{-4}. The computed time scale is then 10^{17}–10^{19} sec. or $10^{9\frac{1}{2}}$–$10^{11\frac{1}{2}}$ years; since the deeper atmospheric layers are the more massive, the higher value is probably more representative than the lower. However, this is an upper limit, since eddy viscosity would be expected to play a role. It is therefore not completely certain that the proposed explanation is correct; but even if the eddy coefficient should be as much as 10^3 times the molecular value, the explanation seems acceptable. If the eddy viscosity were high it would follow that the initial velocity differences were much larger than they are now, which in fact would be expected for a collapsed ring. While this phenomenon is interesting in its implications, it does, however, not change the total mass or angular momentum of the planets involved.

Finally, a word must be said about the concept of *polar wandering*, as it affects our discussion. Glacial deposits in widely scattered areas of the world, including the tropics, coal deposits near the North Pole, and the

positions of the geo-magnetic pole determined from magnetized sediments of approximately known age, have suggested that the position of the pole of rotation in the crust has wandered by tens of degrees even during the last 500 million years (e.g. Runcorn, 1955, *a*, *b*). In explanation of this curious phenomenon, Gold (1955) has pointed out that the location of the axis of rotation within an elastic sphere is unstable and subject to wandering; and that the same is probably true for an elastic-viscous sphere, that is, a body in which the elasticity does not cause an instantaneous but rather a gradual adjustment of its shape to changes in the rotation. Gold further pointed out that if extraneous factors now cause a change in the moments of inertia (e.g. ice caps or new continental masses, floating high on the mantle), then the pole will tend to shift in such a way that the rotation takes place around the shortest undeformed figure axis (the one around which the moment of inertia would be maximum if the rotation did not exist). He did, however, not establish the time scale of this wandering. This has now been done by Burgers (1955) for two cases, of an elastico-viscous earth in which a *sudden* change in the moments of inertia has taken place, and one in which the change, while not sudden, is rapid in the time scale of the pole wandering. The important case, in which the two time scales are of the same order of magnitude, has not yet been solved. Altogether Gold's mechanism looks promising as giving the clue to polar wandering. It may in time give important information on the history of the continents; but it does not appear to affect the problem of the origin of the earth as a whole or the direction of the axis of rotation in space, i.e. the obliquity.

The distribution of continents over the globe may in time give information of more direct astronomic interest. As is well known, this distribution is very uneven, and the analysis of it in terms of spherical harmonics has been used by Vening Meinesz (1951, 1952, 1953) to derive information on the convective regime in the mantle, on the assumption that continents were formed by such convection. (In principle, this could have happened early in the earth's history, when the mantle was perhaps fluid.) He found that a good representation of the mean coefficients of the terms in the second to the tenth spherical harmonics followed from convection, in a mantle of present dimensions; but that the existence of the large first harmonic required a core of less than $0.18R_E$. Chandrasekhar (1952) confirmed the numerical conclusions from a rigorous analysis and Urey (1953) found support from these discussions for his hypothesis that the core formed gradually during geologic time. It is this aspect—when did the earth melt, if ever—that bears on the problems of origin. This question has not yet been clarified; but from discussions with Dr. Chandrasekhar it is my understanding that the introduction of rotation into this problem

may cause important changes. Now the earth must have had a rapid rotation early in its history, when the moon was much closer and most of the angular momentum of the earth-moon system resided in the rotating earth. Chandrasekhar is currently making a new analysis of the problem, taking into account the rotation.

The moon does not appear to be elastico-viscous, contrary to the earth, because for at least 10^9 years it has retained a shape that differs from equilibrium. This perhaps implies that the interior of the moon has cooled substantially below the melting point. Its rotational motion is not free and stability requirements may have caused it to topple over early in its history (Kuiper, 1954, p. 1099). The envelopes of Jupiter and Saturn are so large that they might not have followed even if the interior solid part had turned with respect to the axis of rotation. Such, at least, is suggested by the rotational regime of these envelopes, discussed above.

Solar Dynamical Effects. If during geologic time the sun had either lost or gained mass by a certain factor, the scale of the planetary orbits would have been changed by the same factor, but in the opposite sense. That is, a one-per-cent. mass increase would have caused a to decrease one per cent. Incidentally, the solar luminosity would by this change have increased about three per cent. so that at the planet the sun would have appeared 5 per cent. brighter; the planetary radiation temperature would have increased 1.2 per cent., or 3°C. for the earth.

There is no clear evidence, however, that the sun has been gaining mass. It is often assumed that at least the zodiacal light (caused in part by reflection of sunlight on dust particles of cometary origin and in part by scattering by electrons of solar origin) is evidence for accretion, since the cometary particles spiral inward under the Poynting-Robertson effect. However, before they merge with the sun itself they reach a zone where they will evaporate. It is readily shown that they remain in this zone much longer than is required for complete evaporation. A large particle remains in this zone longer than a small one, proportionally to the particle diameter; but evaporation, likewise, takes proportionally longer. Since the evaporation can be shown to take place for any chosen size, it happens for all sizes. The vapours become rapidly dissociated and ionized, whereupon solar protons and electrons sweep them out of the solar system, as is true for comet tails. The enormous display of the Comet of 1882 shows what happens to cold matter penetrating the solar corona! A similar fate would result for approaching gas. Interplanetary magnetic fields will also inhibit accretion of interstellar gas (Opik, 1954). Thus, *solar accretion* must be very nearly zero.

Solar mass losses are probably more important, though still very small. The electron density near the earth appears to be about 500 per cm.^{3}

(comet tails, zodiacal light, radio whistlers) and the proton density must be similar. The mean outward velocity of these particles is perhaps 300 km./sec. If the solar emission were isotropic, this would, if at a uniform rate, entail a solar mass loss of 0.5 per cent. during geologic time; but since the solar emission depends on latitude, as is indicated e.g. by the isophotes of the polarized component of the zodiacal light (Elsässer, 1953), the loss will be perhaps 0.1 per cent. A still lower value, 0.001 per cent., corresponds to the rate estimated by van de Hulst in 1950 from the appearance of the corona.

Planetary Dynamical Effects. The dynamical properties of the planetary system, evolving under the multiple internal forces resulting from Newton's law of gravitation, can be found with only limited accuracy for the past, the accuracy decreasing as the time interval increases. If the computations were made by numerical integration of the equations of motion, the limit could be made to depend only on the precision of the starting values, which must be found empirically and can never be exact. For very long intervals of time, however, even machine computation would be impossibly slow and costly. Analytical methods must then be used which study the *variations* of the orbital elements by a series of approximations. These approximations may be said to arise as follows: first consider all planets but one to move in undisturbed Kepler orbits, with the one perturbed by the others which are now located at known positions. Each planet is so treated in turn, whereupon the second approximation is found by considering the perturbing planets at their new, perturbed, positions; and so on. The actual series developments for the elements of a planet contain terms in the first, second, third, . . . powers of the masses of other planets,* with coefficients containing, among others, products of infinite series in both the orbital eccentricities and the mutual inclinations. Large numbers of periodic terms of significant amplitude result for each orbital element—which one may ignore as long as each is small enough. In addition, "secular" terms arise, which are those having the time, t, as a factor; these terms are the "dangerous" ones because for large-enough time intervals they will upset the present order of the planetary system. The question of the "stability" of the system revolves largely around the significance of these terms.

Laplace and Lagrange found that in the series containing only the first powers of the disturbing masses, m, no secular terms in a occur and that the secular terms in e and i are in reality sums of periodic terms of long period (10^5–10^7 years, roughly). Poisson found that in the terms containing m^2 there are no secular terms in a but that there are "mixed"

*The masses are expressed in terms of the solar mass and are therefore $<10^{-3}$.

periodic terms, with the amplitude proportional to t. Eginitis (1889) found that in the terms containing m^3 there are secular terms in a but that in the coefficients of these terms the secular changes in e and i of the first order occur, which were found to be in reality periodic, of long period. The same is therefore true for these terms in m^3, though their amplitudes increase with time. Eginitis computed for the earth and Saturn the present rate of change in a due to the secular terms in m^3. Extrapolating these back to $T_g = -4.5 \times 10^9$ years is, of course, most hazardous, if only because the coefficient of t is in reality a fluctuating quantity; but if we do, we find:

Earth, $\Delta a/a = +3.3 \times 10^{-5}$, Saturn, $\Delta a/a = +33$.

Since the theory probably breaks down when $\Delta a \approx 0.1\ a$, the result for Saturn becomes meaningless for $\Delta t > 10^7$ years.

Somewhat more representative may be the calculations of the secular variations of the mean motions, made by Newcomb (1895) for the terrestrial planets and by Brouwer and van Woerkom (1950) for the Jovian planets. Dr. Brouwer has kindly derived the numerical values for the Jovian planets in the form used by Newcomb for the terrestrial planets. The data are combined in Table I, second column. In the third column the value of $\Delta n/n$ has been computed, again by extrapolation to $T_g = -4.5 \times 10^9$ years. The precise meaning of $\Delta n/n$ is not known; if

TABLE I

SECULAR CHANGES IN THE CENTENNIAL MEAN MOTIONS FOR 1950

Planet	Secular change	$\Delta n/n$
	″	
Mercury	−0.0495	+0.004
Venus	+0.0096	−0.002
Earth	−0.0403	+0.014
Mars	+0.0169	−0.011
Jupiter	−0.0032	+0.013
Saturn	+0.0101	−0.10
Uranus	−0.0365	+1.07
Neptune	−0.0008	+0.05

it were, the problem of the long-range stability would be solved. If some or even most of the secular terms are actually parts of periodic terms (such as the series for $\sin ct$), as has been suspected, $\Delta n/n$ may give an upper limit to the true variation. In that case the system of the Jovian planets has not altered appreciably in 5×10^8 years and nothing can be said beyond that.

These numerical data illustrate what has already been expressed by Brown (1932), that the existing planetary theory, for all its incredible

complexity, is not able to make dependable statements for intervals more remote than at most 10^5 years. Now consider for a moment systems like our planetary system, but with planetary masses either much smaller or much larger. In the former case the perturbations would be much less, the series in m, m^2, m^3 . . . being much more rapidly convergent, and the stability would be assured for much longer intervals of time. In the opposite case, with masses approaching the solar mass, no stability whatever could exist, even for short times.

The data of Table I suggest that the mean distances of the terrestrial planets are less subject to change than those of the Jovian planets. This is perhaps not surprising because the masses of the terrestrial planets are some 100 times the smaller, and each planet is perturbed principally by its immediate neighbours, with the asteroid gap isolating the two planet groups to some extent. Since the system of the Jovian planets is known to be stable for at least 10^7–10^8 years, one is tempted to conclude that the system of the terrestrial planets will not have changed appreciably for 10^9–10^{10} years, i.e. the age of the solar system, provided at least that the orbits of the Jovian planets have not changed greatly. Now there are reasons to believe that this condition may be fulfilled. The Jovian planets carry all but 0.16 per cent. of the angular momentum of the planetary system and this must have been conserved. Further, they carry all but 3.1 per cent. of the (negative) energy, and this must have been conserved. The energy among the Jovian planets is very unevenly divided; Jupiter has 84.4%, Saturn 13.8%, Uranus 1.0%, and Neptune 0.8%. Since the energy is proportional to $1/a$, energy exchanges between the planets will not have been able to change Jupiter's distance from the sun appreciably, except if Saturn would have been much closer to Jupiter. This possibility is ruled out later in this paper. It is noted that the simultaneous conservation of angular momentum and energy has a great constraining effect on changes in a; because one varies very nearly as $+a^{1/2}$ and the other as $-a^{-1}$, so that in this approximation simple exchanges, between pairs of planets, are not possible. (The case becomes more complex when slightly eccentric orbits with small mutual inclinations are considered, and the energy and momentum of the sun and the energy of interaction are not neglected; these statements will correspond to the successive theorems on the constancy of a.)

Related to this problem is an important recent study by Hart and Guier (1955) of the statistical properties of N weakly interacting particles in a Newtonian potential, moving in two dimensions. The energy and angular momentum of the planetary system were considered as given and the ultimate radial distribution of N particles derived. A fair agreement with the radial mass distribution among the Jovian planets was found. This

should perhaps be interpreted to mean that (a) the time scale, which was not derived, was insufficient to affect the terrestrial planets (cf. our Table I); (b) the energy and momentum of the Jovian planets are almost equal to the total amounts for the solar system so that the comparison may be regarded as applying to the Jovian planets alone; (c) since the dependence of the time scale on N was not evaluated it may be that the mass distribution computed refers to the pre-planetary solar nebula rather than to the four planets.

We may summarize by saying that two problems must be clearly distinguished: the practical one, of the stability of the planetary orbits during the past 5×10^9 years, and the philosophical one, of the stability of the system for all time to come. One may hope that at least the answer to the former question can be found.

Brown (1932) has pointed out another significant fact. There are certain near-commensurabilities among the periods of the (Jovian) planets ($5\,\mathrm{J} \cong 2\,\mathrm{S} \cdot 2\,\mathrm{U} \cong \mathrm{N}$; $3\,\mathrm{N} \cong 2\,\mathrm{P}$), just as there are such relations in the satellite systems. Motions in these pairs appear to possess a certain stability, i.e. resistance to change by perturbations. This indicates that even if there have been no major changes among the distances of the Jovian planets during geologic time, minor adjustments toward low commensurabilities may have occurred.

In passing we note the very puzzling fact that the four outer satellites of Jupiter on the one hand have orbits that are unstable on the basis of the Jacobi constant (resulting from their peripheral position in Jupiter's sphere of influence), but on the other hand have orbits that are still distinctly similar, indicating a common origin, although they must date back to the formative stage of the planetary system. A similar problem arises with the next group of three stable (i.e. permanent) satellites. These two satellite groups give empirical evidence of amazing long-range stability in the orbital elements that has implications for the general problem of planetary stability which have not yet been evaluated.

The variations of e and i cause these quantities to fluctuate within definite limits during intervals below 10^8 years. What happens for longer intervals is not known. Figure 1 shows the fluctuations of these elements according to Stockwell's integrations, as listed by Charlier (1927). Dots are present values. For Pluto no data are available. With modern values of the masses the fluctuations would be somewhat different but not markedly so.

We have already commented on the uncertainty of the original distances in the satellite systems, owing to the presence of librations which, as Brown has remarked, suggest that the precise initial distances may be even undeterminable. Two satellites, Phobos and the moon, which

the writer (1953*d*, 1954) has considered elsewhere, present special problems. In both cases the distance to the planet has greatly altered. An important new investigation on the *tidal history of the earth-moon system* has just appeared (Gerstenkorn, 1955).

The planetary *obliquities* and the *periods of rotation* will not have changed appreciably during geologic time except for the earth where tidal friction has introduced large changes. According to Darwin (1908) the initial obliquity of the earth was probably about 12° but the initial

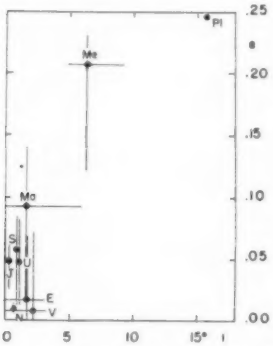

FIG. 1—Inclinations and eccentricities of planetary orbits. *Dots* indicate present values; *lines*, total range of secular variations according to Stockwell.

period of rotation is not known, owing to the uncertain place of origin of the moon; it may have been 5^h–10^h. See also Gerstenkorn (1955).

The principal reasons for assuming that no major changes have taken place in the planetary distances are, at present, general. First there are the conservation laws, of energy and momentum which, as we have seen, greatly limit any rearrangements within the system. Second, there are three empirical facts, the nearly geometric distance law (Bode's law) and the present small e and i values, which do not appear to be the result of any tendency toward equipartition, as would be expected if energy and momentum exchanges had been important. These three properties definitely appear to be *original*, antedating the development of planets as near-point masses; and to stem not from interactions between a few major planets originally moving more or less at random, but from regularized motion, such as can develop only in a flat gaseous disk. We shall therefore assume present values for all dynamical quantities unless a reason is known to do otherwise. The problem will then be to account, at least in a general way, for the system and subsystems so defined.

(*To be continued*)

NOVA HERCULIS 1934: A SUGGESTION

By F. J. M. Stratton†

The recent discovery by Merle F. Walker (1954) that Nova Herculis 1934 is now a close eclipsing binary has roused many speculations. The shortness of the period—4h 39m, the shortest so far found for any binary—has led to a comparison with UX Ursae Majoris, an eclipsing binary with a period of 4h 43m. For this star A. P. Linnell (1950) found densities over 100 times that of early-type stars in the main sequence. The closeness of the stars to each other indicated by the very short period and their high densities have led to the speculation whether G. H. Darwin's (1879) theory of the effect of tidal friction of an external body on a viscous spheroid could be applied to the fainter star of the binary. He showed that, for certain values of the viscosity and of the relative rates of orbital revolution and axial rotation of the spheroid, the stable value of its obliquity to the orbital plane would be about 70°.

In looking for evidence in support of the application of Darwin's work to the nova, one is at once struck by the fact that the major and minor axes of the expanding nova shell have shown marked differences in the distribution of oxygen and nitrogen. In 1943 a number of slit spectrograms were taken by Humason at Mount Wilson Observatory with the slit in different orientations across the shell.* These spectrograms showed strong condensations in the shell at the extremities of the major axis and weaker ones at the extremities of the minor axis. The condensations were stronger in O III, 4959 and 5007A., than in N II, 6548 and 6584A. on the major axis, but of nearly equal strength on the minor axis. In 1945 Baade, photographing the nova at the Cassegrain focus of the 100-inch telescope at Mount Wilson in the green and the red, found that along the minor axis the shell was noticeably weakened in the green, O III, but there was a strong broad band in the red, N II, confirming earlier photographs taken in 1942 (Baade, 1942). The condensations at the end of the major axis remained fairly strong both in the green and the red. Further photographs secured by Baade in 1951 at the Newtonian focus of the 200-inch telescope on Palomar Mountain showed the following features:

(1) No condensations were to be seen in the light of O I, 3727A.

(2) The previous condensations at one end of the major axis was greatly weakened though it could still be observed both in the green and the

†Emeritus Professor of Astrophysics in the University of Cambridge and Honorary Member of the Royal Astronomical Society of Canada.

*These were kindly sent by Dr. Walter S. Adams to the writer to study. Dr. Baade kindly sent copies of the other photographs referred to later.

red. (The shell at the other end of the major axis was affected by a faint stellar image, which had previously been masked by the shell when much brighter.)

(3) The shell was still greatly strengthened at the ends of the minor axis: this strengthening was not at a point but for a short stretch of the shell.

Throughout there was a difference in the behaviour of the major and minor axes of the growing ellipse. We may note that the condensations along the major axis looked like the masses of gas ejected in opposite directions from the star, but they might also be the ansae of a ring lying in the equatorial plane of the brighter star and expanding with the shell. The strengthening of the shell at the ends of the minor axis certainly suggests a broad ring expanding in a plane nearly 90° removed from that of the first ring. The line-of-sight velocities given by the condensations in the spectra of 1943 were small indicating that the two suggested rings were rotating slowly compared with the rate of expansion of the shell.

The suggestion then that I have to make is that under tidal forces the equatorial planes of the two stars are inclined to each other by an angle near to 90° and that rings are expanding in the equatorial planes of both stars. At the dates of the photographs they would be well outside the orbit of the binary star. It is freely admitted that this is a speculative suggestion but it might be worth considering whether it has any application to other binary stars: there are anomalies, not yet fully understood, in the spectra of certain non-stable binaries; can they be resolved if the plane, in which matter appears to be streaming from the smaller component, is not necessarily the plane of the orbit of the binary?

References

Baade, W. S., 1942, *P.A.S.P.*, vol. 54, p. 244.
Darwin, G. H., 1879, *Phil. Trans. Roy. Soc.*, ser. A, vol. 170, p. 447.
Linnell, A. P., 1950, *H.C.O. Circular*, 455.
Walker, M. F., 1954, *P.A.S.P.*, vol. 66, p. 230.

Attention is drawn to the purchase by the Society of a building at 252 College Street, Toronto 2B, for permanent offices and library. See the report of the annual meeting in this issue. Effective May 1 the address of the Society will be changed accordingly.

MINUTES OF THE ANNUAL MEETING OF THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

The 66th Annual Meeting was held at 8:00 p.m. on Wednesday, January 18, 1956, in the McLennan Physics Laboratory, University of Toronto. Dr. John F. Heard, immediate past president, acted as chairman at the request of Dr. R. M. Petrie of Victoria, B.C., who sent his compliments and regrets that distance prevented his presence.

On motion of F. L. Troyer, the Recorder, and of E. J. A. Kennedy, the Minutes of the Annual Meeting of January 14, 1955, were adopted as printed in THE JOURNAL.

The meeting appointed Messrs. Jesse Ketchum and G. A. Cooper as Scrutineers to check and count the ballots returned by mail.

The National Secretary, E. J. A. Kennedy, pointed out in his report that several important matters had been discussed and acted on by the Executive Committee during the year and that these actions had been approved by the National Council; that at the June 8 meeting of Council, the President, Dr. Petrie had expressed a desire to see the Society obtain permanent quarters of its own and that a special committee had then been appointed to seek such premises; that with the advice of Mr. M. A. Altman, C.P.A., the Society's Auditor, several improvements had been made or were soon to be introduced into the office system, and that the standing committee on the Chant Medal had selected Mr. F. J. DeKinder of Montreal as recipient for the year.

The National Treasurer, J. H. Horning, then presented the financial statement, and the Librarian, Dr. J. B. Oke, reported on accessions to the Library.

These three reports were received.

The Scrutineers then returned to report that a majority of the ballots were cast in favour of the names as printed thereon, and Dr. Heard declared these elected as Officers and Council for 1956.

Mr. Horning presented the report of the special committee, comprising Dr. Heard and himself, named by Council on June 8 to investigate suitable permanent quarters. It was not until January 10 that such a property, in a convenient location and within the Society's means, was found, he stated. On that date the committee inspected a house at 252 College Street which had been placed on the market to settle an estate. While the original price asked was $50,000, it was indicated an offer of $32,500 would be considered. Prompt action being necessary, Dr. Heard arranged that a group of members of the Executive Committee and some others inspect the property that evening. This group, comprising Dr.

Heard, Mr. Horning, Mr. Troyer, Dr. Oke, Mr. Altman and Mr. C. Frank Publow decided the property was admirably suited to the Society's needs and that the price was reasonable. Dr. Petrie was informed by telephone and both he and Mr. Kennedy (who inspected the premises the next day) advised purchase. The three-storey house is of brick with slate roof, situated on a 40-foot lot, with a double garage at the rear. The four front rooms on the ground floor were considered for the Society's office and Library use, leaving a small apartment downstairs for a caretaker, and three self-contained apartments on the upper floors which would be rented to provide funds to cover maintenance costs and mortgage interest, and probably some reduction of the mortgage principal. Following favourable comment by an impartial real estate adviser, the offer to purchase was signed by the Treasurer and a $1,500 deposit made, Mr. Horning reported.

On motion of Mr. Horning and Miss Northcott, the Annual Meeting voted approval of the action taken by the Executive Committee in purchasing the property; and appreciation of the services of the special committee in locating such a suitable home for the Society was added by members present.

On motion of Miss Northcott and Mr. Ketchum, the Meeting authorized the use of the special funds of the Society (Building Fund, Southam Press Fund and Life Membership Fund) to whatever extent might be needed to meet the $12,500 down payment.

Members present discussed and approved a financial campaign to seek donations both from members, and from governmental and charitable foundation sources, to fittingly furnish the new quarters and to reduce the mortgage as much as possible. Dr. Heard announced that two members, immediately upon hearing of the decision to purchase, made unsolicited donations of $2,000 and $100. The meeting approved a motion by Mr. Horning and Miss Northcott that an appeal for donations be made.

Notice of motion having been given in the notice of the Annual Meeting, it was moved by Mr. Kennedy and Miss Northcott that the National Council prepare a revised Constitution and By-Laws and that this be submitted to the membership for voting upon. Carried.

There was some discussion on the need for increasing the Society's revenue to meet increased printing and office expenses, and it was pointed out that the 1956 OBSERVER'S HANDBOOK actually cost almost 50 cents per copy to cover printing, wrapping and postage. On motion of Mr. Kennedy and Mr. J. H. Sled of Hamilton Centre, Council was requested to consider an increase in the price of the HANDBOOK to non-members; and on motion of Mrs. K. M. Heaton and Mr. Paul

Almond, Council was asked to consider the advisability of increasing membership fees.

The meeting voted expressions of appreciation for the services during the year of the members of the Executive Committee, the special committee on premises, and especially to Miss Northcott, the Assistant Editor; Dr. Oke, the Librarian, and Mr. Altman, the Auditor, for the work they had done without monetary compensation.

The meeting then adjourned.

FREDERIC L. TROYER, *Recorder.*

REPORT OF THE NATIONAL SECRETARY

During 1955 a number of very important items have come up for discussion first by the Executive Committee, followed by approval and action by the National Council. On recommendations by the Society's Auditor, Mr. M. Altman, C.P.A., the present office system is to be completely revised. His proposals, it was agreed, would make for greater efficiency and better accounting, benefiting the whole Society. He also recommended that the date of the Annual Meeting be set forward to allow ample time for the preparation of the financial and other reports. The Society is indebted to Mr. Altman for his generosity in giving his time and counsel.

A special meeting of Council was held June 8th, important not only for the decisions made, but because we had the pleasure of having our President, Dr. Petrie, in the chair. The meeting was also notable in that we had more Centres represented than at any time in this writer's memory. The following cities were represented: Victoria, Vancouver, Toronto, London, Hamilton, Ottawa, and Montreal. Following a suggestion of the President that the Council give careful consideration to finding a better location for the headquarters of the Society when our lease terminated this year in May, the Council appointed a committee (Dr. Heard and Mr. Horning) who will present their report at this meeting. It is also to be remembered that Dr. Petrie wrote personally outlining his ideas to the full membership of the Society following this Council meeting.

In order to implement the recommendation to fix a more suitable date for the Annual Meeting, it is necessary to revise the Constitution and by-laws, and as there are other changes needing attention a motion will be brought before this Annual Meeting for approval. A special committee was appointed for study and to make a report during the year for ratification at the next Annual Meeting. This committee is composed as follows: the President, First Vice-President, National Secretary, National Treasurer, and Mr. Altman, the Auditor.

We rejoice with our First Vice-President, Dr. Helen Hogg, in the honour of her appointment as Program Director for Astronomy for the National Science Foundation, Washington. The appointment is for one year. In the meantime, we miss her gracious presence and wise counsel at our meetings.

Last year no nominations for the Chant Medal came from any of the Centres. This year, however, we are pleased to announce that the judges had four candidates for their deliberation. The winner for 1955 is Mr. F. J. DeKinder of Montreal Centre. He has been notified of his success, and we hope to see him at our At-Home in February when presentation can be made in person.

The Society has suffered greatly in 1955 by deaths. Eleven members have passed away. Among them was Dr. J. W. Campbell, a life-long enthusiast of astronomy in the Edmonton Centre, and a past president of the national Society. Captain C. A. MacDonald, president of Vancouver Centre, died in November. Toronto Centre mourns the loss of George T. Dale who was known to us as a generous friend and a most valued worker. Windsor's secretary writes that their Honorary President Judge J. J. Coughlin died in November.

Because of lack of complete information from all sources, the total figures of our membership cannot be given accurately. From figures on hand we feel sure the total will be much in excess of 2000. The list of members unattached to centres showed a marked increase. Two new life members have been added to the U.S. list.

The office secretary, Mrs. Williamson, reports that the incoming correspondence has been greatly increased in the last year due principally to requests for information. The OBSERVER'S HANDBOOK answers most of these queries. The HANDBOOK is becoming increasingly popular. Six thousand copies were printed for 1956. Already the sales so early in the year are very much higher than any previous year and may indicate that the increased printing will not be sufficient to supply the demand. I think it no exaggeration to say that our HANDBOOK is unique and superior to any other publication of its kind. The Society is indebted to the small group who are responsible for its preparation and particularly to the Assistant Editor, Miss Ruth Northcott.

Our newest Centre at Halifax has had a successful first year, increasing their members. Their report makes interesting reading and shows that they are quite active.

We appreciate the Centres' promptness in furnishing the Council with their yearly reports and necessary information for the Office.

E. J. A. KENNEDY, *National Secretary.*

REPORT OF THE LIBRARIAN

During the past year the library has acquired 33 new books. Some of these were left to the Society by the late Mr. George T. Dale. Others were given to the Society by various members. The remaining were bought from a donation given by Mr. Carl Reinhardt. In addition to these books the library receives 38 journals and periodicals as well as publications from a great many observatories.

The supply of back issues of the JOURNAL, which is kept to fill orders for old copies, has been completely sorted. Useless material was discarded and the remainder was put in an easily accessible form. During the course of this sorting it was found that the supply of a few numbers was very low or even exhausted. These numbers are:

Vol. 37, No. 2 (Feb. 1943)
Vol. 39, No. 7 (Sept. 1945)
Vol. 40, Nos. 8–9 (Oct.–Nov. 1946)
Vol. 48, No. 1 (Jan.–Feb. 1954)

It would be much appreciated if members who have these numbers and do not wish to save them would send them to the national headquarters. They will be paid for at the rate of fifty cents a copy if such payment is requested.

It is hoped that in the coming year ways can be found to make the library more useful to all members of the Society by (a) indicating to members through the JOURNAL what material is in the library and (b) by re-organizing a loan-by-mail system. All requests for library material will be welcomed.

J. B. OKE, *Librarian.*

REPORTS OF SECRETARIES OF CENTRES

TORONTO CENTRE

A special meeting at which the Astronomer Royal, Sir Harold Spencer Jones, was our guest; development of the newly-formed Observation and Study Group and further expansion of the Telescope Makers Group were highlights of the year's activities in the Toronto Centre.

The Centre's telescope display which was provided each evening at the Canadian National Exhibition, from August 26 to September 10, attracted more than 5,000 visitors who observed the heavens through several telescopes, and in many cases also admired the telescopes constructed by our members. We are grateful, for the ninth year, to *The Toronto Star* for making possible the distribution of our "Sky Facts" folder.

Membership in the Centre continued to grow with 83 new members elected during the year. We regret to report the death, on May 13, of Mr. George T. Dale, an active amateur member who had served several times on Council and who had been a generous contributor to both the Toronto Centre and the Society's National Council.

The regular meetings (held in the McLennan Physics Laboratory, University of Toronto, unless otherwise noted), were:

February 8—Members' Night. Tour of three laboratories in the U. of T. Physics department. H. L. Welsh, Ph.D., gave introductory remarks.
February 22—M. A. Preston, Ph.D., McMaster Univ.: "The Origin of the Universe."
March 8—Visit to Spitz Planetarium at McMaster University, as guests of the Hamilton Centre.
March 22—Miss Ruth J. Northcott: "The Message of Light."
April 5—Members' Night. David J. Gerrie: "Gravitation and Centripetal Force."
May 7—Sir Harold Spencer Jones: "Life on Other Worlds." (In Convocation Hall, U. of T., with members of Royal Canadian Institute and Royal Meteorological Society, Canadian Branch, as our guests.)
May 31, June 28, July 26—Summer "Star Nights" with telescopes on U. of T. campus.
August 26 to September 10—Telescope Display nightly at Canadian National Exhibition.
September 27—Annual Members' Visit to David Dunlap Observatory, Richmond Hill.
October 18—J. F. Heard, Ph.D., Miss Ruth J. Northcott and J. B. Oke, Ph.D.: "Destination Dublin—and Beyond."
November 1—Members' Night. L. H. Clark led discussion on observing by amateurs.
November 12—Gerard P. Kuiper, Ph.D., Yerkes Observatory: "The Formation of the Planets." (A joint meeting with the Royal Canadian Institute in Convocation Hall.)
November 29—Annual meeting of the Centre and film programme.

The Observation and Study Group held seven meetings at which papers were given on varied subjects, also two observing nights and several informal get-togethers for discussion and observation. The Group has inaugurated a monthly bulletin listing objects suitable for observation and results of such observing. Although limited in numbers, the Study Group finds a close-knit group an advantage in discussing topics considered a little too "heavy" for regular meetings of the Centre.

The Telescope Makers Group held 16 meetings, usually in homes of Group members (to whose wives, or mothers, they wish to express thanks for a warm reception) and in addition several members were at the David Dunlap Observatory nearly every Saturday night, providing telescopes to augment the visitors' programme provided by the Observatory staff. A dozen members completed telescopes during the year and many others built new mounts or other equipment. To this Group also must go much of the credit for making our Exhibition display a success.

FREDERIC L. TROYER, *Secretary*.

OTTAWA CENTRE

Four meetings of the council were held during the year to arrange for the public meetings and to transact the business of the Centre.

Seven public lecture meetings were held, and on the occasion of the address by the Astronomer Royal a dinner was arranged at which members had an opportunity to meet Sir Harold and Lady Spencer Jones.

January 13—C. S. Beals: "Understanding the Universe."
February 10—L. Voyvodic: "Properties of Cosmic Radiation."
March 10—N. W. Broten: "Exploring the Universe by Radio."
May 9—Sir Harold Spencer Jones: "The Expanding Universe."
October 18—A. E. Douglas: "Comets."
November 8—Motion pictures and slides: "Photographing the 1954 Total Eclipse from the Air."
December 6—Annual dinner meeting. J. L. Locke: "Utilization of Solar Energy."

IAN HALLIDAY, *Secretary.*

HAMILTON CENTRE

During the year 1955, seven regular meetings and one joint meeting with the Hamilton Association for the Advancement of Science, Literature and Art were held at McMaster University, one field night and one council meeting to discuss the business of the Centre.

January 6—W. J. Sled, B.A.: "Theories of Planetary Motions;" J. H. Sled, Phm.B.: "Navigational Aids."
February 12—M. A. Preston, Ph.D.: "Theories of the Origin of the Universe."
March 3—W. D. Stewart, B.A.: "Asteroids;" G. E. Campbell, M.A.: "Comets."
April 7—N. D. Lane, M.A., Ph.D.: "Stellar Atmospheres."
May 5—H. B. Fox: "Telescope Mountings;" T. M. Norton: "Light and the Telescope."
July 25—Field night.
October 6—W. J. McCallion, M.A.: "Astronomical Miscellany."
November 3—W. S. Mallory, M.A.: "Principles of the Refracting Telescope;" E. Ostrosser: "Famous Refractors."
December 1—N. Green, B.A.: "Synthetic Satellites;" J. F. Heard, Ph.D.: "Highlights of the Dublin Meeting of the International Astronomical Union."

The total membership is 83 and includes three life members.

GEORGE MURCHIE, *Secretary-Treasurer.*

WINNIPEG CENTRE

During 1955 one of the events of importance was the astronomical exhibit at the Winnipeg Auditorium lasting ten days and which drew an estimated crowd of three thousand people. In the exhibit were a Junior Spitz Planetarium, a book-corner and a display of instruments.

Observations were planned for the Perseid, Orionid and Leonid meteors; the first two showers were observed successfully, the third was clouded out. All results were sent to the Dominion Observatory.

The University arranged two programmes: a weekly summer observation session for summer school students, and a series of twelve lectures in the winter under the auspices of the Department of University Extension and Adult Education.

During the year a number of members re-formed the telescope-building group which has been inactive for a while.

During the year six regular meetings and one special meeting were held:

January 19—V. G. Martens: Presidential Address; R. J. Lockhart: "The Use of the Handbook."
January 31–March 5—Astronomical Exhibit at the Winnipeg Civic Auditorium.

April 1—J. L. Locke, Ph.D.: "Eruptions on the Surface of the Sun."
May 26–27—Observation nights (cloudy).
June 13—R. M. Petrie, Ph.D.: "Finding the Distance to the Stars."
October 24—Wilbur Jonsson: "The Sky This Month;" R. J. Lockhart: "Meteor Observations;" Miss N. Tweedie: "The Chubb Crater—Ungava's Claim to Fame;" G. Marcy Wiseman: "Some Reflections from the David Dunlap Observatory, Summer 1955."
November 16—A. B. Lowe, M.A.: "Through the North-west Passage."
December 19—Annual meeting.

G. Marcy Wiseman, *Secretary-Treasurer.*

VICTORIA CENTRE

During the year 1955 the Victoria Centre held seven regular meetings and one special meeting:

January 12—K. O. Wright: "Eclipse of the Sun."
January 26—O. Struve: "Life on Other Planets."
February 9—D. B. McLay: "Radio Astronomy."
March 9—J. B. Warren: "Nuclear Astronomy."
April 13—G. Shaw: "Einstein and the Universe."
October 12—R. M. Petrie: "Clocking the Stars."
November 9—J. A. L. Muir, R. S. Evans, D. H. Andrews: "Telescopes to Make and to Use."
December 7—Annual dinner; A. McKellar: "World Astronomers Meet."

The 1955 membership stands at 80 including 6 life members and 7 junior members.

In 1955 the Centre offered its twenty-fourth annual summer course "Summer Evenings with the Stars" to an enrolment of 110 persons. The five meetings included lectures followed by observational periods.

August 1—Mrs. J. R. Noble: "The Panorama of the Sky."
August 8—R. O. Redman: "The Sun."
August 15—Visit to the Dominion Astrophysical Observatory.
August 22—E. H. Richardson: "The Motions and Nature of the Planets."
August 29—S. G. Hacker: "Some Aspects of Cosmogony and Cosmology."

The regular meetings of the Victoria Centre were held in the auditorium of the Normal School–Victoria College Building, at 8:00 p.m.

Dorothy M. Edmonds, *Secretary-Treasurer.*

MONTREAL CENTRE

After losing our observatory at Wilson Avenue about two years ago our future looked very bleak. Fortunately we were able to secure the use of an abandoned building on the upper McGill Campus and during the present session active measures were taken to transform this building into an observatory. An appeal made to the members met with a most generous response, both in money and the offer of voluntary labour. The observatory soon began to take shape.

During the year one of our oldest and most highly esteemed members, Mr. Horsley Townsend, unfortunately passed away. His membership of the Montreal Centre, however, had given him such pleasure that he left us a large and handsome legacy in his will. This enabled us to speed up progress to such an extent that the observatory is now almost complete and ready for use and we look forward to making useful contributions to astronomical knowledge. We hope to commemorate Mr. Townsend's legacy by memorial lectures to be given from time to time by distinguished astronomers.

Although much time was devoted to the construction of the observatory the normal activities of the centre continued with customary vigour. The telescope class and the

star night at Westmount Park were temporarily discontinued, but the lectures and observation meetings were carried on with great success. Courses on the Solar System, given by some of the members of the centre, and lectures delivered by guest speakers were all well attended. Miss Ruth Northcott gave us a lucid account of the Spectroscopic Binaries, Dr. McNamara likewise dealt with the Aurora Borealis and Dr. Menzel, the director of the Harvard College Observatory, dealt in an interesting manner with Flying Saucers. The last topic attracted an audience of over 200 people. In comparison with the session 1953–1954 the attendance at the lectures during 1954–1955 was much the same but the attendance at the meetings held at the new observatory was substantially higher.

The 1954–1955 session was undoubtedly a memorable session and we can look forward to the future with confidence.

CHARLES FOX, *Secretary.*

LONDON CENTRE

During 1955 the London Centre held six regular monthly meetings, and three meetings of the executive council. All meetings were held in the Hume Cronyn Memorial Observatory of the University of Western Ontario. Observations were made through the ten-inch refractor when weather permitted.

Circumstances made it necessary to postpone the Annual Meeting from December to January. The list of meetings is as follows:

January 21—E. E. O'Connor: "Space Travel."
March 25—Miss Ruth J. Northcott: "The David Dunlap Observatory and Radial Velocities."
April 30—W. H. Adamson: "The Measurement of Time;" H. R. Kingston: "Handbook Study."
May 10—H. R. Kingston: "The Use of Star Maps;" G. R. Magee: "The Conjunction of Jupiter and Uranus."
October 21—W. G. Graham: "Atomic Energy and the Sun."
November 18—W. H. Wehlau: "Artificial Satellites;" Mrs. E. Smith: "Handbook Study."

W. GORDON GRAHAM, *Secretary.*

VANCOUVER CENTRE

There were seven regular meetings of the Vancouver Centre in 1955, all in the Physics Building of the University of British Columbia through the kindness of the University and Dr. Shrum. The attendance varied between 47 and 17 with a mean of about 30. The speakers were:

January 11—B. N. Moyls, Ph.D.: "The Moving Cluster in Ursa Major."
February 8—G. A. Morgan: "A Survey of the Heavens."
March 8—Norman Barton, M.A.: "The Motion Picture in Astronomy."
April 12—Members' Night; Capt. C. A. McDonald: "Ocean Currents;" A. W. Mackenzie: "Southern Constellations from a South Pacific Atoll."
October 11—R. J. Clark: "Polar Wandering."
November 8—A. Outram: "The Satellites of Jupiter."
December 13—A. M. Crooker, Ph.D.: "Testing and Figuring Telescope Mirrors."

The Telescope Section had ceased to function during the war. To revive it there was a meeting on March 22. Thirty attended. There were meetings of the Section with demonstrations on April 26, October 25 (when Mr. Edward Hedgecock was elected Leader and Mr. C. V. B. Corbet, Deputy), and on November 22. About eight persons are making mirrors.

As usual the Centre put out telescopes on the University Grounds on suitable evenings on Tuesdays during June, July and August. The Centre had no telescopes at

the Pacific National Exhibition this year. The Annual Dinner was in Brock Hall on December 13. Twenty-seven members and guests attended. The Annual Meeting was held in the Physics Building after the dinner.

Captain C. A. McDonald, President of the Centre and a member for twenty-five years, died on November 26.

Thirteen new members joined during the year and there are now 52 on the roll.

R. J. CLARK, *Secretary.*

EDMONTON CENTRE

The regular meetings of the Edmonton Centre were held in the Arts and Science Building of the University of Alberta through the kindness of the authorities. The attendance varied from 20 to 52. Refreshments after the meetings were much appreciated. The annual dinner was held in the Corona Hotel.

A course of lectures on Elementary Astronomy was organized and held in the "Observatory Annex", with nearly twenty people registered. News and observing reports were continued in "Stardust" and occasionally given by members of the group at meetings. Four members of the group were named Honorary Demonstrators in Astronomy by the Physics Department and the University Observatory Committee.

The HANDBOOK talks have been given by various members. The Centre misses Dr. Campbell, our founder and Honorary President for many years, for these talks, for the many other contributions he made to the meetings and the running of the Centre's business, and of course, for himself, with his geniality and unfailing good cheer.

The main papers of the past year were as follows:

December 10—Frank Page: "European Travel Slides."
January 13—L. M. Cowin: "Time Keeping."
February 10—Handbook Quiz organized by Earl Milton.
March 10—E. H. Gowan: "The Zodiac."
April 14—L. E. Gads: "Astronomical Co-ordinates" and three films.
May 12—E. R. Reinelt: "Seeing Through the Air."
October 13—Debate: "Resolved that successful human travel in inter-planetary space is possible." Affirmative: H. Grayson-Smith, Arthur Dalton. Negative: E. S. Keeping, Franklin Loehde.
November 10—D. R. Crosby: "The Structure of the Universe."

E. H. GOWAN, *Secretary.*

CENTRE DE QUEBEC

Le Centre de Québec n'a pas tenu séances mensuelles régulières, au cours de l'année, sauf celle du 26 février, qui était consacrée à l'étude des miroirs de télescope par le test de Foucault et à la rédaction du bulletin de contrôle.

L'activité s'est concentrée autour de l'Observatoire, où comme à l'accoutumé le public était admis durant les premières heures de la soirée. Cependant, comme résultat du travail accompli par le Comité de l'Observatoire, et un peu aussi grâce à une température vraiment exceptionnelle tout le long de l'été, le nombre des visites a plus que triplé, cette année, en regard de l'année dernière. En plus de jeter un coup d'œil à l'oculaire des instruments, nos visiteurs pouvaient assister, cet été, à de courtes conférences qui les préparaient à ce qu'ils allaient voir sous la coupole. Elles furent fort appréciées et nous en remercions l'auteur, M. François Baby.

Le Comité de l'Observatoire a été institué par la société avec mission d'organiser une souscription populaire en faveur du futur observatoire de Québec et de faire la publicité qui convient autour du projet. La souscription elle-même durera trois années ou plus, suivant le montant qu'il faudra obtenir. La campagne de cette année n'a pas

rapporté pour la peine, au point de vue financier, mais elle a été un grand succès publicitaire. On doit remarquer ici un fait très significatif: vingt-sept pour cent, et même au delà, de nos souscripteurs ne demeuraient pas dans la région même de Québec.

L'almanach graphique du ciel de l'Académie des Sciences du Maryland, publié pour la onzième année, accuse toujours le même gain de popularité. Il est maintenant tiré à 5000 exemplaires.

PAUL-H. NADEAU, *Le Secrétaire.*

WINDSOR CENTRE

Nine regular meetings were held during 1955 and one executive meeting. The average attendance at meetings was 73. The meetings were as follows:

January—Taylor Russell, Detroit Astronomical Society: "The Eclipse of the Sun in 1954" with motion pictures; L. Huneault: "Current Events."
February—Cyril B. Hallam, leader, Russell Warwick, moderator: Panel discussion on "Flying Saucers;" Chas. A. Bell: "Current Events."
March—Dean B. McLaughlin, Ph.D., University of Michigan: "The Latest Findings on the Surface of Mars;" D. C. Bawtenheimer: "Current Events."
April—O. C. Mohler, Ph.D., McMath-Hulbert Observatory: "Findings of New Interest on the Sun;" W. G. Mitchell: "Current Events."
May—John Huschilt, Assumption College: "The Spectrum." Members were taken on a tour of the Science Building through the courtesy of Father Ruth.
June—Held at the home of Mr. and Mrs. D. C. Bawtenheimer. Mrs. Chas. A. Bell: "Travelogue."
September—Lee F. McGee, W. D. Lowe Vocational School: "Modern Science;" D. C. Bawtenheimer: "Current Events."
October—Father N. J. Ruth, C.S.B., Dean of Arts and Sciences, Assumption College: "Measurement of Temperature and its Application to Astronomy;" W. G. Mitchell: "Current Events."
November—Annual meeting.

PERCY C. HAWKES, *Secretary.*

HALIFAX CENTRE

The most notable advance made during the last year was the affiliation of the Nova Scotia Astronomical Society with the Royal Astronomical Society of Canada. Word of our acceptance by the National Council was received about January 15, 1955. From that date our society has been known as the Halifax Centre of the Royal Astronomical Society of Canada.

A very interesting course of lectures was arranged by the programme committee, consisting of Major C. A. Anderson, Dr. Wm. Bridgeo and Mr. R. L. Baglow. The programme consisted of the following:

R. Hornstein: "Is our Climate Changing?"
John Longard: "Earth, the Water Planet."
S. Heeps: "Radio Astronomy."
R. L. Baglow: "Radio Astronomy."
Fr. Burke-Gaffney: "Report on the Astronomical Congress in Dublin."

Our news letter was out of circulation for a time because of the inadequacy of the duplicator being used. With the full consent of the membership a better machine was purchased for $90.00. Two thirds of the debt already has been paid from donations to the Society and it is gratifying to report that the news letter, now called the "Stargazer," is back, bigger and better than ever.

During the past year the membership has shown a steady increase and I believe the future looks very bright indeed.

B. J. EDWARDS, *President.*

THE ROYAL ASTRONOMICAL SOCIETY OF CANADA
STATEMENT OF REVENUE AND EXPENDITURE
FOR YEAR ENDED DECEMBER 31, 1955

REVENUE

Membership fees received through R.A.S.C. Centres		$ 2,905.00	
Fees received from members not attached to Centres		1,306.89	
Grant from Government of Canada		3,000.00	
Grant from the Province of Ontario		500.00	
Donations and miscellaneous contributions		1,276.50	
Sale of Publications:			
Subscriptions to Journal	$ 690.41		
Observer's Handbooks	1,348.60		
Special issues and reprints	694.25		
	$2,733.26		
Less: Agents' discounts	195.42		
		2,537.84	
Advertising revenue		247.40	
Interest earned by Life Membership Fund		66.50	
TOTAL REVENUE			$11,840.13

EXPENDITURE

Grants to R.A.S.C. Centres for 1954	$ 1,332.50	
Printing cost of publications	6,847.11	
Office salaries	2,630.00	
Rent	720.00	
Stationery and supplies	474.18	
Office and general expenses	253.07	
Library expenses	63.68	
Postage and express (less amount charged out)	182.68	
Telephone	103.96	
Bank charges	41.43	
Office equipment acquired during year	150.00	
TOTAL EXPENDITURE		$12,798.61
NET DEFICIT FOR YEAR		$ 958.48

STATEMENT OF SURPLUS AND DEFICIT
FOR YEAR ENDED DECEMBER 31, 1955

Surplus brought forward from previous year	$865.41
Excess of expenditure over revenue for year ended December 31, 1955	958.48
Net deficit – December 31, 1955	$ 93.07

THE ROYAL ASTRONOMICAL SOCIETY OF CANADA
BALANCE SHEET – DECEMBER 31, 1955

ASSETS

Current Assets		
Cash in bank and on hand	$ 9,173.96	
Accounts receivable (publications and advertising)	508.81	
		$ 9,682.77
Funds Held for Special Reserves		
Invested in bonds of Government of Canada, Bell Telephone Co. of Canada and others (Market value $10,552.92)	$10,800.00	
On deposit in bank	2,601.21	
		13,401.21
Total Assets		$23,083.98
DEFICIT – Current Account		93.07
		$23,177.05

LIABILITIES

Current Liabilities		
Outstanding cheques	$ 4,039.71	
Accounts payable	1,138.20	
		$ 5,177.91
Deferred Revenue		
Membership fees paid for 1956 and subsequent years	$ 801.38	
Prepaid subscriptions to Journal	93.05	
Prepaid orders for 1956 Observer's Handbooks	171.50	
Prepaid advertising	32.00	
Grant from Government of Canada for 1956	3,500.00	
		4,597.93
Special Reserves		
Life Membership Reserve	$ 2,542.66	
Building Fund Reserve	8,907.85	
Southam Press Fund Reserve	1,950.70	
		13,401.21
		$23,177.05

R. M. Petrie, *National President.* J. H. Horning, *National Treasurer.*

AUDITORS' REPORT

We have examined the books and accounts of The Royal Astronomical Society of Canada for the year ended December 31, 1955 and have received all the information and explanations we have required.

In our opinion, the accompanying balance sheet and related statement of revenue and expenditure present fairly the financial position of the Society as at December 31, 1955 and the results of its operations for the year ended on that date, according to the best of our information, the explanations given us and as shown by the books and records of the Society.

Toronto, Ontario,
January 31, 1956.

Morris Altman and Company
Certified Public Accountants

II. REPORTS OF TREASURERS OF CENTRES

TORONTO CENTRE

General Account

Receipts		Disbursements	
Balance—January 1, 1955	$ 523.90	Bulletins, printing and postage	$ 115.15
Grant from National Council	486.00	Meeting room rentals	30.69
Centre's share of 1955 fees	380.00	Expenses *re* two joint meetings with Royal Canadian Institute	214.50
Contribution from member	35.00	At-Home and Special Events	110.73
		General and office expenses	18.00
		Balance—December 31, 1955	935.83
Totals	$1,424.90		$1,424.90

Special Purpose Fund

Receipts		Disbursements	
Balance—January 1, 1955	$1,097.02	Installation of new speaker in Public Address System	$ 26.40
Annual grant from C.N.E.	200.00	Balance—December 31, 1955	1,421.72
Bank interest earned for year	17.25		
Accumulated interest transferred from Membership Fees Trust Acct.	133.85		
Totals	$1,448.12		$1,448.12

Membership Fees Account

Receipts		Disbursements	
Accumulated interest	$ 102.17	Remitted to National Council	$1,200.90
Fees received for 1955	1,140.00	Share of fees transferred to General Account	380.00
Donations	440.90	Interest transferred to Special Purpose Account	133.85
Interest earned for year	31.68		
Totals	$1,714.75		$1,714.75

M. Altman, *Treasurer.*

OTTAWA CENTRE

Receipts		Disbursements	
Balance from 1954	$ 164.70	Fees to National Treasurer	$ 436.00
Members' fees: 1955	246.00	Printing, postage and stationery	64.84
1956	150.00	Advertising	64.47
Life	40.00	Donations	94.00
Grant from National Council	84.00	Expenses of dinner meetings	209.25
Donations (National Office)	94.00	Cost of Handbooks	64.00
(Ottawa Centre)	10.00	Projection services	10.00
Sale of Handbooks	44.00	Bank charges	1.27
Bank interest	1.94	Balance carried forward	121.56
Proceeds of dinner meetings	230.75		
Totals	$1,065.39		$1,065.39

S. A. Mott, *Treasurer.*

HAMILTON CENTRE

Receipts		Disbursements	
Balance from 1954	$ 89.45	Fees to National Treasurer	$204.00
Members' fees	165.00	Rent	46.54
Grant from National Council	71.00	Postage and stationery	25.00
Donations	28.45	Printing	19.52
Bank interest	1.24	Miscellaneous (exchange)	.35
Field Night	21.53	Balance carried forward	81.26
Totals	$376.67		$376.67

George Murchie, *Treasurer.*

WINNIPEG CENTRE

Receipts		Disbursements	
Balance from 1954	$113.95	Fees to National Treasurer	$177.00
Members' fees	186.00	Miscellaneous	110.92
Miscellaneous	7.00	Balance carried forward	71.03
Grant from National Council	52.00		
Totals	$358.95		$358.95

G. Marcy Wiseman, *Secretary-Treasurer.*

VICTORIA CENTRE

Receipts		Disbursements	
Balance from 1954	$ 84.21	Fees to National Treasurer	$152.00
Members' fees	217.00	Postage and stationery	15.62
Grant from National Council	88.00	Printing	20.09
Bank interest	.93	Bank charges	2.21
Summer Course profit	67.62	Insurance	10.00
		Express	4.19
		Travelling expenses	13.15
		Miscellaneous	9.99
		Balance carried forward	230.51
Totals	$457.76		$457.76

Dorothy M. Edmonds, *Secretary-Treasurer.*

MONTREAL CENTRE

Receipts		Disbursements	
Balance from 1954	$ 546.15	Fees to National Treasurer	$ 516.00
Members' fees: 1954	27.00	Postage and stationery	153.59
1955	696.00	Rent	78.00
1956	6.00	Expenses *re* meetings	106.60
Life	40.00	Library	13.46
Donations	95.58	Equipment	57.00
Grant from National Council	258.00	Dues—Film Council	5.00
Bank interest	7.21	Insurance	98.79
Insurance refund	12.50	Exchange on cheques	3.07
Recovered from Observatory Fund	251.90	Light and fuel	40.90
		Moving expenses	18.00
Townsend Bequest	25,000.00	Presentation	56.45
		Miscellaneous	15.75
		Observatory fund	251.90
		Balance carried forward	25,525.83
Totals	$26,940.34		$26,940.34

Observatory Fund

Receipts		Disbursements	
Balance from 1954	$1,713.52	Alterations to building	$2,991.77
Donations	1,813.69	Telescope (on account)	200.25
Interest on bonds	3.00	Freight on telescope	51.65
Bank interest	3.93	Bank charges	.75
		Balance carried forward	289.72
Totals	$3,534.14		$3,534.14

C. N. S. Yarnell, *Treasurer.*

LONDON CENTRE

Receipts		Disbursements	
Balance from 1954	$ 1.01	Fees to National Treasurer	$ 72.00
Members' fees: 1955	63.00	Expense *re* meetings	38.88
1954	9.00	Exchange on cheques	.30
Grant from National Council	27.00	Donations (National Office)	14.00
Donations (National Office)	14.00	Balance carried forward	.83
Donation (Local Centre)	10.00		
Loan	2.00		
Totals	$126.01		$126.01

W. Gordon Graham, *Treasurer.*

VANCOUVER CENTRE

Receipts		Disbursements	
Balance from 1954	$ 84.35	Fees to National Treasurer	$159.00
Members' fees	159.00	Donations	23.00
Grant from National Council	35.35	Postage	11.00
Bank interest	1.15	Balance carried forward	109.85
Donations	23.00		
Totals	$302.85		$302.85

C. A. Rogers, *Treasurer.*

EDMONTON CENTRE

Receipts		Disbursements	
Balance from 1954	$156.70	Fees to National Treasurer	$135.00
Members' fees	129.00	Donations	7.00
Associates' fees	3.00	Flowers	3.00
Donations	7.00	Purchase of book	5.40
Grant from National Council	57.00	Rent of film	5.00
Bank interest	4.41	Stationery and postage	24.45
		Expenses *re* meetings	21.72
		Exchange on cheques	.30
		Balance carried forward	155.24
Totals	$357.11		$357.11

H. J. Montgomery, *Treasurer.*

QUEBEC CENTRE

Receipts		Disbursements	
Balance from 1954	$ 27.31	Fees to National Treasurer	$270.00
Members' fees	249.80	Observatory	58.73
Grant from National Council	74.00	Administration	186.15
Grant from Provincial Gov.	400.00	Publicity campaign	286.84
Loan	116.62	Balance carried forward	74.13
Miscellaneous	3.50		
Bank interest	4.62		
Totals	$875.85		$875.85

PAUL-H. NADEAU, *Treasurer.*

WINDSOR CENTRE

Receipts		Disbursements	
Balance from 1954	$ 71.89	Fees to National Treasurer	$169.00
Members' fees	160.00	Stationery	.90
Grant from National Council	42.00	Expenses *re* meetings	40.00
Donations	24.00	Subscription, *Sky & Telescope*	5.00
Bank interest	1.04	Honorarium to Janitor	3.00
		Windsor Education Council	2.00
		Flowers	7.00
		Balance carried forward	72.03
Totals	$298.93		$298.93

Number of Junior Members included in this report: 2.

W. J. PERSON, *Treasurer.*

CENTRE FRANÇAIS DE MONTREAL

Receipts		Disbursements	
Balance from 1954	$122.94	Fees to National Treasurer	$ 96.00
Members' fees	155.00	Rent	12.00
Grant from National Council	58.00	Postage, stationery and printing	33.34
Donations	74.00	Expense *re* meetings	12.18
Bank interest	2.77	Miscellaneous	20.25
One booklet sold	.25	Subscription to *R.A.S.*	30.00
		Balance carried forward	199.79
Totals	$412.96		$412.96

FLEURANGE LAFOREST, *Secretary-Treasurer.*

The Royal Astronomical Society of Canada

OFFICERS FOR 1956

NATIONAL OFFICERS AND COUNCIL

Honorary President—The Honourable W. J. DUNLOP, Minister of Education for Ontario.
President—R. M. PETRIE, PH.D, Victoria.
First Vice-President—HELEN S. HOGG, PH.D., Toronto.
Second Vice-President—GORDON R. MAGEE, PH.D., London.
National Secretary—E. J. A. KENNEDY, 13 Ross Street, Toronto.
National Treasurer—J. H. HORNING, M.A., 13 Ross Street, Toronto.
Recorder—FREDERIC L. TROYER, Toronto.
Librarian—J. B. OKE, PH.D., Toronto.
Council—D. C. BAWTENHEIMER, Windsor; Rev. M. W. BURKE-GAFFNEY, Halifax; J. A. BUTEAU, Montreal; BRIAN COCKHILL, Montreal; H. B. FOX, Hamilton; MRS. K. M. HEATON, Toronto; R. J. LOCKHART, Winnipeg; D. A. MACLULICH, Ottawa; ANDREW MCKELLAR, PH.D., Victoria; E. E. O'CONNOR, London; E. PHIBBS, Edmonton; G. M. SHRUM, PH.D., Vancouver; OSCAR VILLENEUVE, Quebec.

TORONTO CENTRE

Honorary President—C. A. CHANT, PH.D.
President—H. L. WELSH, PH.D.
First Vice-President—GRANT A. COOPER
Second Vice-President—C. FRANK PUBLOW, B.A.SC.
Secretary—FREDERIC L. TROYER, 53 Woodlawn Avenue East, Toronto 7.
Recorder—RAYMOND R. BROADFOOT
Treasurer—M. A. ALTMAN, C.P.A.
Council—ADAM BELL; KURT FRENKEL; DAVID J. GERRIE, B.A.SC.; D. A. MACRAE, PH.D.; MRS. ETHEL M. MORGAN, M.D.; W. R. SHERRICK; F. W. TOMINGAS, M.D.; W. T. TUTTE, PH.D.; J. B. WALLACE, and the *Past Presidents*—E. J. A. KENNEDY; J. R. COLLINS; S. C. BROWN; REV. D. W. BEST, D.D.; MISS RUTH J. NORTHCOTT, M.A.; JOHN F. HEARD, PH.D.; F. L. TROYER; W. R. HOSSACK and L. H. CLARK.
Director of Telescope Makers Group—JESSE KETCHUM, 7 Thirteenth Street, Toronto 14.

OTTAWA CENTRE

Honorary President—HOYES LLOYD
President—A. E. COVINGTON
First Vice-President—J. E. LILLY
Second Vice-President—IAN HALLIDAY
Secretary—D. L. G. MILLER, Dominion Observatory, Ottawa.
Recorder—MISS J. D. B. STEWART
Treasurer—S. A. MOTT
Representative Observers' Group—GORDON GRANT
Council—MRS. IAN HENDERSON; F. W. MATLEY; W. L. ORR; J. A. ROTTENBERG; R. W. TANNER; and *Past Presidents*—P. M. MILLMAN; D. A. MACLULICH; J. L. LOCKE.

HAMILTON CENTRE

Honorary President—W. T. GODDARD, B.S., E.E.
President—J. H. SLED, PHM.B.
First Vice-President—REV. N. GREEN, B.A., L.TH.
Second Vice-President—W. J. SLED, B.A.
Secretary-Treasurer—GEORGE MURCHIE, 77 Fennel Avenue West, Hamilton.
Curator—G. E. CAMPBELL, M.A.
Council—J. G. CRAIG, B.SC.; P. EWANICK; W. K. HARRIS; A. E. JOHNS, PH.D.; L. O. JONES; E. LANGLEY; R. LEEDS; W. S. MALLORY, M.A.; W. J. MCCALLION, M.A.; T. M. NORTON; O. J. PATON; C. PIERSON; F. SCHNEIDER; W. D. STEWART, B.A.; B. WISHART.

WINNIPEG CENTRE

Honorary President—H. H. SAUNDERSON, PH.D.
President—R. J. LOCKHART
Vice-President—G. MARCY WISEMAN
Secretary-Treasurer—T. CAIRNS, 924 Waterford Ave., Winnipeg 9.
Recorder—MISS N. TWEEDIE
Council—J. L. GREEN; C. R. PUNSHON; G. L. SADLER; J. SCATLIFF; W. W. WRIGHT; and *Past Presidents*—D. R. P. COATS; V. G. MARTENS; *President Emeritus*—L. T. S. NORRIS-ELYE.

VICTORIA CENTRE

Honorary President—K. O. WRIGHT, PH.D.
President—MISS JEAN K. MCDONALD, PH.D.
First Vice-President—E. R. GIBSON
Second Vice-President—N. G. ROGERS
Secretary-Treasurer—D. H. ANDREWS, Dominion Astrophysical Observatory, Royal Oak.
Recorder—J. I. D. JERVIS
Director of Telescopes—ROBERT PETERS
Librarian—O. W. SMITH
Council—E. R. BROWN; N. HUTCHINGS; C. D. MAUNSELL; J. A. L. MUIR; W. STILWELL; F. R. WILLIAMS.

MONTREAL CENTRE

Honorary President—G. Harper Hall
Honorary Vice-President—A. N. Shaw, Ph.D.
President—Charles M. Good
Vice-President—Henry F. Hall
Secretary—Charles Fox, Ph.D., 381 Prince Albert Ave., Montreal.
Recorder—E. E. Bridgen
Treasurer—C. N. S. Yarnell
Librarian—Miss I. K. Williamson
Director of Observations—F. DeKinder
Council—W. H. Birtles; A. L. Burran; Brian Cockhill; A. M. Donnelly; D. Frappier; S. B. Lindsay; T. Topham; W. A. Warren; and *Past President*—D. E. Douglas, Ph.D.

LONDON CENTRE

Honorary President—H. R. Kingston, Ph.D.
Vice-President—Omar Kilburn
President—W. Gordon Graham
Treasurer—G. R. Magee, Ph.D.
Secretary—W. H. Wehlau, Ph.D., University of Western Ontario, London.
Council—H. H. Giles; Mrs. E. Smith; W. B. Wortman; W. H. Adamson; Dr. G. F. Walden; and *Past President*—E. E. O'Connor.

VANCOUVER CENTRE

Honorary President—A. M. Crooker, Ph.D.
Vice-President—A. W. Mackenzie
President—Earle M. Price
Treasurer—Mrs. C. A. Rogers
Secretary—R. J. Clark, Ph.D., 1988 Western Parkway, Vancouver 8.
Directors of Telescope—E. Hedgecock; C. V. B. Corbet.
Council—C. W. Deans, M.Sc.; James Duncan; H. W. Fowler, M.A.; G. E. Frostrup; Mrs. Elda Grant; D. Inge; M. A. McGrath; G. A. Morgan; F. Stedman; and *Past Presidents*—A. Outram; M. T. Spence.

EDMONTON CENTRE

President—D. R. Crosby
Vice-President—L. V. Smith
Secretary—E. H. Gowan, Ph.D., University of Alberta, Edmonton.
Treasurer—H. G. Montgomery
Librarian—E. S. Keeping
Council—Miss C. Hicks; E. Milton; S. F. Page; M. B. Stewart; V. C. Williams.

QUEBEC CENTRE

Patron—Mgr. Alphonse-Marie Parent, P.A., V.G.
1er Vice-Président—l'abbé Rosario Benoit
Président—J.-Alfred Dumont
2e Vice-Président—Lionel-Pierre Peloquin
Secrétaire-trésorier—Paul-H. Nadeau, 229-Ouest, rue St-Cyrille, Quebec 6.
Conseil—Francois Baby; Georges-Henri Boulet; l'abbé Benoit Denis; Rene Doucet; Maurice Drolet; l'abbé Rosaire Fortin; Lloyd McWilliams; Jean-Paul Richard; Oscar Villeneuve; et les *anciens Présidents*—Jean-Chs. Magnan; Lucien Pouliot; Georges-Etienne Gagne; Albert Duberger.

WINDSOR CENTRE

Honorary President—His Honour Judge J. J. Coughlin, B.A.
President—Wm. G. Mitchell, B.R.I.
Vice-President—R. C. Bradley, M.A.
Secretary—Percy C. Hawkes, 1855 Kildare Road, Windsor.
Treasurer—Wm. J. Person, R.I.A.
Librarian—L. Huneault
Council—D. C. Bawtenheimer; C. A. Bell, B.A. O.C.; C. K. Carrington; Hugh S. Cunningham, B.A.; Cyril B. Hallam, B.A.; W. Almon Hare, B.A.Sc.; Edward W. Keith; Henry Lee; John W. Loaring; Cameron Montrose, B.A.; Gus A. Nyberg; Gregory Rawlings, B.A.; W. L. Swanson, M.A.; Russell G. Warwick, B.A.

CENTRE FRANÇAIS DE MONTREAL

Président—Jean Asselin, Ing.P.
Vice-Président—Roger Bonin
Secrétaire-trésorier—Mlle Fleurange Laforest, 76 Deslauriers Ave., Ste-Genevieve par. Co Jacques-Cartier.
Rapporteur—Gaston Lebrun
Bibliothécaire—J. E. Guimont
Directeur des Observations—Jean Naubert
Conseil—Hector Collette; DeLisle Garneau; Mlle Marcelle Gauvreau; J. R. Grignon; J. E. Guimont; Gaston Lebrun; Fr. Robert, f.e.c.; J. P. Laviolette; Mlle Georgette Le Moyne; Jean Naubert; A. D. Tessier, M. D.

HALIFAX CENTRE

Honorary President—Rev. Fr. M. W. Burke-Gaffney, S.J.
President—James Paul
First Vice-President—Major C. A. Anderson
Treasurer—M. H. Goodwin
Second Vice-President—V. J. Pothier, J.P.
Secretary—Basil Nowe, 24 Harbour Drive, Dartmouth
Librarian—W. A. Bridgeo
Council—G. W. G. Allen; R. L. Baglow; W. F. Dawson; B. J. Edwards; Henry O'Shea, B.J.

METEOR NEWS

By Peter M. Millman, *National Research Council, Ottawa*

The Frequency of Faint Meteors

I have received some interesting notes from Mr. Walter S. Houston, Manhatten, Kansas, concerning the observation of faint meteors. Mr. Houston, a member of the A.A.V.S.O., uses a 6-inch telescope with a 20 × eyepiece giving a real field 3°.4 in diameter. With this instrument he finds unexpectedly high rates for faint meteors, up to 12–25 per hour for non-shower nights. These meteors are near the limit of visibility (12.5 magnitude on good nights) and, like all careful observers, Mr. Houston is a bit cautious concerning phenomena of this type. He wonders if they could be a psychological effect. However, observing with a 50-mm. instrument and a wide angle 8 × eyepiece, he does not see these large numbers of faint objects. There is other evidence in the literature for the high frequency of faint meteors down to the 10th or 12th magnitude and I am inclined to consider the chances as better than even that these Kansas observations are of real objects. It is an interesting study for those with rich-field telescopes of 4 to 10 inches aperture. We still know all too little about the meteors fainter than 3rd magnitude. I should be glad to hear from those who have made observations of this type.

Mr. Houston also reports an interesting shower of faint meteors seen with the unaided eye on the night of Aug. 17/18, 1955. He estimates between 100 and 200 meteors observed in the period 2314 to 2328 hrs. C.S.T., all radiating from a point about a degree north of κ Cygni. The observer's threshold for stars was at the time 7.1 or 7.2 stellar magnitude. The meteors ranged from 5th to 7th magnitude in brightness. The coincidence of this date and radiant with the κ Cygnids listed in the Journal last year (vol. 49, p. 173, 1955) is striking, and these must represent the faint portion of a shower which has been detected at Harvard through photography of the very bright members.

Corrections to Lists of Meteor Showers

Two provisional lists of meteor showers have been published recently in these columns, Journal, vol. 48, p. 194, 1954; vol. 49, p. 173, 1955. In connection with the day-time showers, recorded at the Jodrell Bank station of the University of Manchester, I have had a letter from Dr. G. S. Hawkins suggesting a revision in the listing as a result of more recent

work with improved radio equipment. He suggests the following corrected values for the first list:

Shower	$\lambda\odot$	Mean Evening Date	Radiant α	Radiant δ	Rate	Duration
ζ Perseids	75°	June 6	62°	+24°	40	15 days
Arietids	75	June 6	44	+23	60	20
β Taurids	97	June 28	87	+23	28	12

Dr. Hawkins also feels that there is now some doubt as to the reality of the day-time showers tabled in the second, or supplementary, list. He therefore suggests deleting the following six showers:

Piscids (May)	α Orionids	ν Geminids
54 Perseids	λ Geminids	θ Aurigids

Meteor Observations by the Montreal Centre

Miss I. K. Williamson reports from Montreal that during 1955 the Centre was hampered by bad weather on most of the meteor programmes which they planned. Their Lyrid observations were completely clouded out and their Perseid observations at Hemmingford ended after an hour looking through scattered clouds. One of their members at Deep River, Miss E. A. Taylor, organized an observing group and had better luck with the Lyrids. Mr. I. A. Laur in Montreal plotted δ Aquarids at the end of July. A brief summary of these observations is given below:

1. Deep River, Ont., lat. 46°06′ N, long. 77°29′ W.
April 22/23, 1955—weather clear.

Personnel: A Cameron, Miss M. Cliff, T. Drew, Miss I. W. Hay, J. M. Kennedy, G. E. Lee-Whiting, A. E. Litherland, H. McManus, W. T. Sharp, Miss E. A. Taylor.

In 150 minutes of observing between 2230 hrs and 0200 hrs, E.S.T., 39 Lyrids and 9 Non-Lyrids were observed and plotted.

2. Montreal, P.Q., lat. 45°28′N, long. 73°37′ W.
July 29/30, 1955—weather clear.

Personnel: I. A. Laur.

In period 0000–0400 hrs 25 meteors were plotted.

3. Hemmingford, P.Q., lat. 45°03′ N, long. 73°35′ W.
August 12/13, 1955—scattered cloud to complete overcast.

Personnel: B. Bemina, E. E. Bridgen, A. L. Burran, Miss M. Clark, B. Cockhill, F. DeKinder, D. E. Douglas, Miss O. Giroux, A. Grenier, Miss R. Jamieson, B. Jones, A. Laur, A. R. MacLennan, J. Morrison, T. Noseworthy, R. Venor, Mrs. D. Yane, D. Zackon, Mrs. K. Zorgo.

In period 2200–2302 hrs 11 meteors were plotted.

Orionid Observations at Ottawa in 1955

The Dominion Observatory and the National Research Council had much the same trouble as Montreal with the weather in 1955. However, the recently-formed Observers' Group of the Ottawa Centre of the Society made a very good start by observing Orionid meteors on two clear nights in October. These observations were organized by Messrs. Bill Gault and Stanley A. Mott. The details of the programme are given below:

4. South Gloucester, Ont., lat. 45°16'.9 N, long. 75°34'.5 W.

Oct. 21/22, 1955—weather clear.

Oct. 22/23, 1955—clear until 0100 hrs, then cloud.

Personnel: A. E. Covington, Wm. Gault, J. Holbrook, S. A. Mott, W. L. Orr, R. Watters.

A total of 139 meteors was observed on the first night and 84 on the second, when the programme was cut short by bad weather. The meteors were divided into Orionids, Taurids and Non-shower, though in many cases considerable doubt exists as to which category a meteor belongs to. I have revised some of the original estimates on the basis of the plotted trails. The total numbers of all meteors seen in each 20-minute period are listed in Table I, and these are followed by the reduced hourly rates for the three categories. On the average two observers were on duty all the time and the reduction to 6 observers has been carried out through use

TABLE I

E.S.T.	Oct. 21/22, 1955				Oct. 22/23, 1955			
	Meteors observed	Hourly Rates (6 observers) O	T	N	Meteors observed	Hourly Rates (6 observers) O	T	N
(hrs.)								
2230–2250					3			
–2310	6	15	6	20	7	9	16	22
–2330	11	17	4	13	10	15	17	21
–2350	4	27	10	13	11	29	23	15
–0010	14	23	9	13	14	30	17	13
–0030	6	24	13	18	7	40	17	19
–0050	10	21	13	20	19	37	17	29
–0110	13	25	13	23	13	43	20	40
–0130	9	22	9	17				
–0150	2	16	7	18				
–0210	5	24	4	18				
–0230	11	40	5	30				
–0250	19	50	2	21				
–0310	8	46	4	17				
–0330	8	31	6	11				
–0350	9	28	9	10				
0350–0410	4	43	11	9				
Totals	139				84			

of the factors published in the JOURNAL, vol. 28, p. 139, 1934. For corresponding times the Orionid rates were higher on the second night. The Taurids also seemed more active on Oct. 22/23. Observed magnitude distributions for the two nights together are given in Table II.

TABLE II

Magnitude	−4	−3	−2	−1	0	1	2	3	4	5	Totals	Mean Magnitude
Orionids	1		1	1	6	1 6	2 20	11 34	3 13	6 1	106	2.50
Taurids					1	1 1	1 9	1 14	4 6	2 2	42	2.92
Non-shower	1			1	1	6	1 13	6 24	2 15	2 3	75	2.75

Mr. Gault carried out a programme of meteor photography along with the visual observations. Five cameras were used with focal lengths ranging from 50 mm. to 105 mm. and aperture ratios from F/3.5 to F/4.5. Two of the cameras were equipped with 30° prisms and a rotating shutter occulted the lenses 26 times per second. Three direct photographs were secured. The best of these has been reproduced in figure 1. It is of an

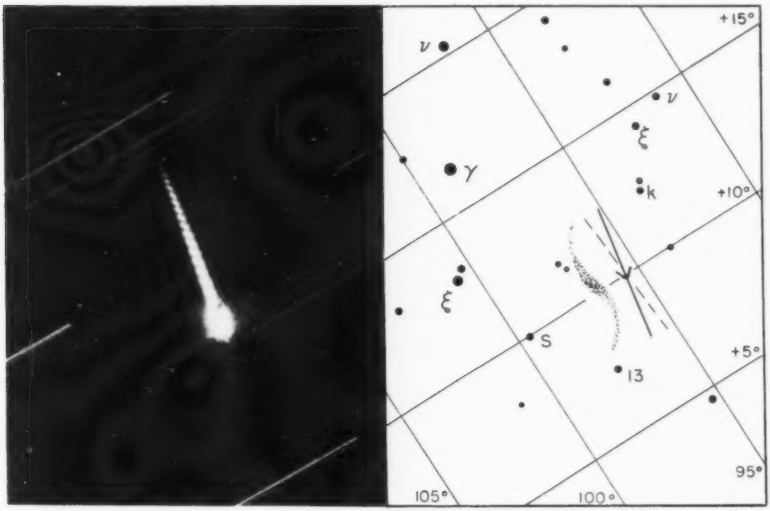

FIG. 1, *Left*—Orionid fireball, $01^h\ 59^m\ 14^s$ E.S.T., Oct. 22, 1955, visual magnitude −4, photographed at South Gloucester with F/3.5 lens, focal length 80 mm., shutter breaks 26 per sec., Eastman Kodak Tri X emulsion. Stars identified on photograph are in Monoceros, exposure ended at $02^h\ 08^m\ 00^s$ E.S.T.

Right—Visual plot of fireball. *Broken line*—original visual plot; *solid line*—visual plot adjusted to agree with direction of photographic trail; *dotted figure*—visual persistent train after 25 seconds.

Orionid meteor of visual magnitude −4, with a visual trail about 5 degrees long and centre 5 degrees from the radiant. The persistent train of this meteor was visible to the naked eye for 25 seconds. Deformation by upper atmosphere winds was clearly evident in this time as illustrated by the visual plot of the train. The brightness of the train for the first few seconds was estimated as 0 magnitude. The interesting corkscrew-like appearance of the photographic trail is a different effect, resulting from a combination of rotating shutter and the somewhat elongated coma images produced at the edge of the camera field.

I should like to congratulate the Ottawa observers' group on their results and wish them good luck in the future. Several members of this group have turned out consistently to help with the programmes of the Dominion Observatory and the National Research Council but this is the first time they have organized observations on their own.

NOTES FROM OBSERVATORIES

DOMINION ASTROPHYSICAL OBSERVATORY, VICTORIA, B.C.

Staff. Dr. Anne B. Underhill was granted leave of absence from the Observatory to spend the academic year 1955–1956 as a teaching member of the staff of Harvard College Observatory. Mr. W. G. Milne has been on leave to pursue graduate studies in Seismology at Berkeley.

Dr. Andrew McKellar has been elected President of the Astronomical Society of the Pacific. He attended the Third Annual Conference of the Western Spectroscopy Association, held at Berkeley on January 26, giving an invited paper on molecules in the solar system. In February he attended the Second Joint Meeting of the West Coast Observatories at Pasadena, where the topic of discussion was instrumentation.

Dr. R. M. Petrie visited eastern Canada in February, where he attended the At-Home of the Society in Toronto on February 17, and gave the Presidential address. He visited also in Ottawa, Winnipeg and Edmonton, addressing the Winnipeg and Edmonton Centres of the Society.

Dr. K. O. Wright will attend the meetings of the American Astronomical Society to be held in Columbus in March.

Instruments. The photoelectric exposure meter mentioned in the last report of this Observatory has been in use since November. It has given every satisfaction and has proved to be superior even to the judgment of experienced observers in estimating correct exposures, and has allowed us to obtain perfectly exposed spectrograms during the unsettled winter weather. The construction and use of such a meter is to be highly recommended.

The single-prism quartz spectrograph has been completed and is now in operation. With this instrument it is possible to obtain spectra of relatively faint stars to the limit of atmospheric transmission.

A new Bausch and Lomb grating, blazed in the first order in the ultraviolet, was mounted and put into operation in the stellar spectrograph. This enables us to photograph stellar spectra in the region $\lambda\lambda$3000–4400 with a linear dispersion of 16 A./mm.

Visitors. The Hon. George Prudham, Minister of the Department of Mines and Technical Surveys, was a distinguished visitor at the Observatory on October 5. During his visit he inspected some of the equipment of the Observatory, and addressed a meeting of the staff.

Dr. D. M. Popper of the University of California (Los Angeles) spent several days here in August, studying our spectrograms of a number of eclipsing binaries.

Other visitors to the Observatory included Mr. M. H. Rogers and Dr. G.N. Lance of King's College, London; Dr. R. Gaudry, President of the Chemical Institute of Canada; Dr. W. Ford, Director of the Pacific Naval Laboratory; Dr. E. A. Kaempffer of the University of British Columbia; and Dr. W. Petrie of the Defence Research Board.

J. K. McD.

UNIVERSITY OF NEW BRUNSWICK OBSERVATORY, FREDERICTON, N.B.

Observatory Given Official Name. The interest and support of the University Senate in the restoration of this historic building has been manifested once more by their recent action in passing a resolution that the Observatory be henceforth designated as "The Brydone Jack Observatory."

Full credit must be given to Professor W. S. MacNutt of the History Department for initiating this action. It was quite apparent to him that while the memory of other staff members of King's College, in the period 1850–60, had been perpetuated by the erection of suitable plaques at the University, no such recognition had ever been accorded Dr. Jack.

During that decade, the staff consisted of Jack, Robb and d'Avray in addition to the Head of the College, Dr. Jacob. James Robb, professor of chemistry and natural history, 1837–1861, and Joseph Marshall Baron d'Avray, professor of modern languages, 1848–1871, served not only King's College (later, the University of New Brunswick) with distinction, but also the Province of New Brunswick. This broader service was likewise rendered by Dr. William Brydone Jack.

It is very gratifying that this resolution should be passed at a time when Brydone Jack, the pioneer founder of the Observatory which now bears his name, has received recognition for his service to Canadian astronomy, extending far beyond the confines of his adopted province.

J. E. K.

An Important "First"

The HISTORY of the TELESCOPE

By H. C. KING

First book in English that tells such a full story of the evolution of telescopes. For the amateur and professional alike. With a foreword by the Astronomer Royal.

443 pp. and index
196 illustrations
$12.50 postpaid

Exclusive Western Hemisphere Publishers
SKY PUBLISHING CORPORATION
Eastern: Charles Griffin and Co., London

C-40 Harvard Observatory
Cambridge 38, Mass.

MONTREAL CENTRE

Honorary President—G. Harper Hall
Honorary Vice-President—A. N. Shaw, Ph.D.
President—Charles M. Good
Vice-President—Henry F. Hall
Secretary—Charles Fox, Ph.D., 381 Prince Albert Ave., Montreal.
Recorder—E. E. Bridgen
Treasurer—C. N. S. Yarnell
Librarian—Miss I. K. Williamson
Director of Observations—F. DeKinder
Council—W. H. Birtles; A. L. Burran; Brian Cockhill; A. M. Donnelly; D. Frappier; S. B. Lindsay; T. Topham; W. A. Warren; and *Past President*—D. E. Douglas, Ph.D.

LONDON CENTRE

Honorary President—H. R. Kingston, Ph.D.
Vice-President—Omar Kilburn
President—W. Gordon Graham
Treasurer—G. R. Magee, Ph.D.
Secretary—W. H. Wehlau, Ph.D., University of Western Ontario, London.
Council—H. H. Giles; Mrs. E. Smith; W. B. Wortman; W. H. Adamson; Dr. G. F. Walden; and *Past President*—E. E. O'Connor.

VANCOUVER CENTRE

Honorary President—A. M. Crooker, Ph.D.
Vice-President—A. W. Mackenzie
President—Earle M. Price
Treasurer—Mrs. C. A. Rogers
Secretary—R. J. Clark, Ph.D., 1988 Western Parkway, Vancouver 8.
Directors of Telescope—E. Hedgecock; C. V. B. Corbet.
Council—C. W. Deans, M.Sc.; James Duncan; H. W. Fowler, M.A.; G. E. Frostrup; Mrs. Elda Grant; D. Inge; M. A. McGrath; G. A. Morgan; F. Stedman; and *Past Presidents*—A. Outram; M. T. Spence.

EDMONTON CENTRE

President—D. R. Crosby
Vice-President—L. V. Smith
Secretary—E. H. Gowan, Ph.D., University of Alberta, Edmonton.
Treasurer—H. G. Montgomery
Librarian—E. S. Keeping
Council—Miss C. Hicks; E. Milton; S. F. Page; M. B. Stewart; V. C. Williams.

QUEBEC CENTRE

Patron—Mgr. Alphonse-Marie Parent, P.A., V.G.
1er Vice-Président—l'abbé Rosario Benoit
Président—J.-Alfred Dumont
2e Vice-Président—Lionel-Pierre Peloquin
Secrétaire-trésorier—Paul-H. Nadeau, 229-Ouest, rue St-Cyrille, Quebec 6.
Conseil—Francois Baby; Georges-Henri Boulet; l'abbé Benoit Denis; Rene Doucet; Maurice Drolet; l'abbé Rosaire Fortin; Lloyd McWilliams; Jean-Paul Richard; Oscar Villeneuve; et les *anciens Présidents*—Jean-Chs. Magnan; Lucien Pouliot; Georges-Etienne Gagne; Albert Dubberger.

WINDSOR CENTRE

Honorary President—His Honour Judge J. J. Coughlin, B.A.
President—Wm. G. Mitchell, B.R.I.
Vice-President—R. C. Bradley, M.A.
Secretary—Percy C. Hawkes, 1855 Kildare Road, Windsor.
Treasurer—Wm. J. Person, R.I.A.
Librarian—L. Huneault
Council—D. C. Bawtenheimer; C. A. Bell, B.A. Q.C.; C. K. Carrington; Hugh S. Cunningham, B.A.; Cyril B. Hallam, B.A.; W. Almon Hare, B.A.Sc.; Edward W. Keith; Henry Lee; John W. Loaring; Cameron Montrose, B.A.; Gus A. Nybero; Gregory Rawlings, B.A.; W. L. Swanson, M.A.; Russell G. Warwick, B.A.

CENTRE FRANÇAIS DE MONTREAL

Président—Jean Asselin, Ing.P.
Vice-Président—Roger Bonin
Secrétaire-trésorier—Mlle Fleurange Laforest, 36 Deslauriers Ave., Ste-Genevieve par. Co Jacques-Cartier.
Rapporteur—Gaston Lebrun
Bibliothécaire—J. E. Guimont
Directeur des Observations—Jean Naubert
Conseil—Hector Collette; DeLisle Garneau; Mlle Marcelle Gauvreau; J. R. Grignon; J. E. Guimont; Gaston Lebrun; Fr. Robert, f.e.c.; J. P. Laviolette; Mlle Georgette Le Moyne; Jean Naubert; A. D. Tessier, M. D.

HALIFAX CENTRE

Honorary President—Rev. Fr. M. W. Burke-Gaffney, S.J.
President—James Paul
First Vice-President—Major C. A. Anderson
Treasurer—M. H. Goodwin
Second Vice-President—V. J. Pothier, J.P.
Secretary—Basil Nowe, 24 Harbour Drive, Dartmouth
Librarian—W. A. Bridgeo
Council—G. W. G. Allen; R. L. Baglow; W. F. Dawson; B. J. Edwards; Henry O'Shea, B.J.

THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

VOL. L, NO. 2 MARCH–APRIL, 1956 WHOLE NO. 419

PAGE

Articles

Finding the Distances to the Stars ..... *R. M. Petrie* 49
The Formation of the Planets, Part I ..... *Gerard P. Kuiper* 57
Nova Herculis 1934: a Suggestion ..... *F. J. M. Stratton* 69

Annual Meeting of the R.A.S.C.

Minutes of Meeting 71
Report of the National Secretary 73
Report of the Librarian 74
Reports of Secretaries of Centres 75
Report of the National Treasurer 81
Reports of Treasurers of Centres 83
Officers for 1956 88

Meteor News

The Frequency of Faint Meteors; Meteor Observations by the Montreal Centre; Orionid Observations at Ottawa in 1955 .... *Peter M. Millman* 90

Notes from Observatories

Dominion Astrophysical Observatory (*J. K. McD.*); University of New Brunswick Observatory, Fredericton, N.B. (*J. E. K.*) 95

Address of Editors: David Dunlap Observatory, Richmond Hill, Ont.

Business correspondence and remittances should be addressed to J. H. Horning, Treasurer of the Society, 13 Ross Street, Toronto 2B.
$3.00 per annum, Single number, 50 cents.
Subscription to the JOURNAL is included in membership fee.